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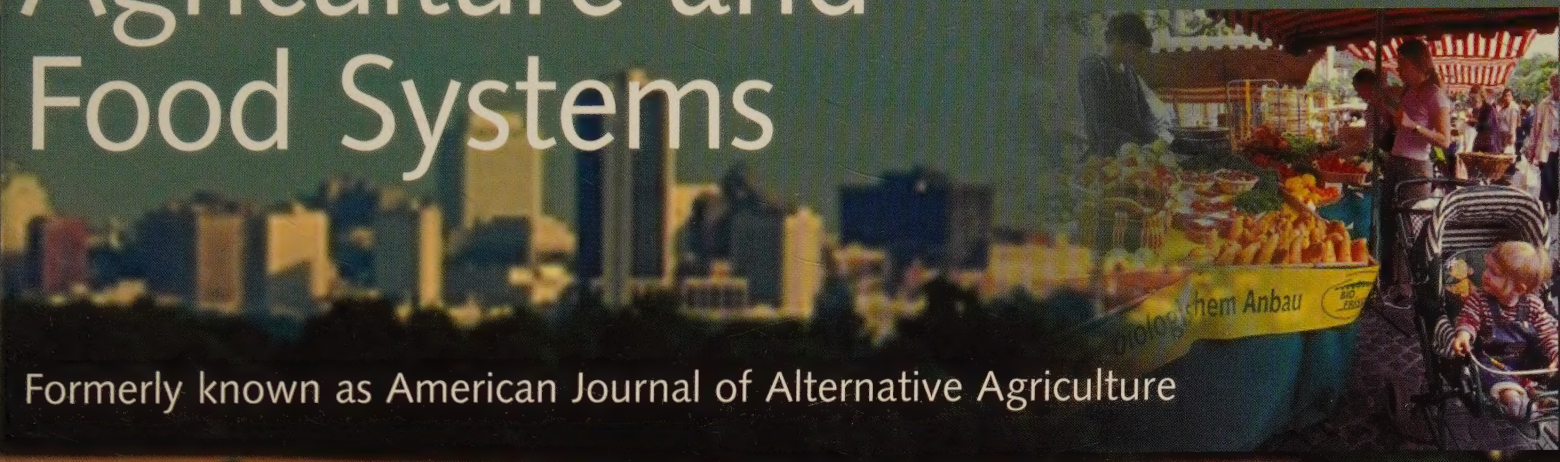

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Renewable Agriculture and Food Systems provides an international forum for original research and review articles on the biological, physical, social science, and policy aspects of alternative agriculture and food systems, focusing on the effective use of renewable resources and biodiversity in agro-ecosystems. The journal particularly welcomes multidisciplinary, holistic, systems research that addresses the multiple challenge of economically meeting basic human needs for food, fiber, and energy while maintaining essential natural and environmental resources.

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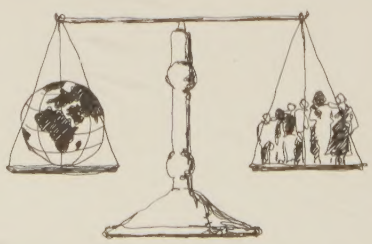

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Brassica cover cropping for weed management: A review

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Abstract

Cover crops offer many benefits for farmers seeking to reduce their reliance on external inputs. These include maintaining and improving soil quality, preventing erosion and, in some cases, allelopathic weed control. Allelopathic potential has been well documented for cover crops such as cereal rye (*Secale cereale* L.), hairy vetch (*Vicia villosa* Roth) and red clover (*Trifolium pratense* L.). Much less is known about other potentially allelopathic cover crops, including certain brassicaceous species that are normally grown for their oilseeds, including canola and rapeseed (both *Brassica napus* L.) and mustards (e.g., *Sinapis alba* L., white and yellow mustard). Because of their potential contribution to pest management, there is increased interest in growing brassicas, both as cover crops and as seed crops harvested for oil production. In this review, we first discuss unique attributes of brassicas that make them promising options for pest management, as well as generally beneficial cover crops. Next, we review the literature from controlled settings on the effects of brassicas, brassica extracts and isolated compounds contained therein on seed germination, seedling emergence and establishment, and seedling growth—effects that, combined or taken alone, could contribute to reducing the density and vigor of weed communities in the field. Field studies examining the detrimental effects of brassicas in rotation with other crops, as well as examining the effects of brassica cover crops on weed dynamics in subsequent crops, also are reviewed. Finally, we review some important agronomic considerations about the use of brassica cover crops.

Key words: brassicas, cover crop residues, green manure, allelopathy

Introduction

One of the hallmarks of sustainable agriculture systems is the use of multiple tactics to address short- and long-term goals concerning pest and soil management. In this context, single tactics that provide multiple benefits are of vital importance. The practice of cover cropping is such a tactic, providing many services to agroecosystems, including improved soil quality, increased nutrient cycling and pest management[1]. Given the prominence of weeds as a production-related problem for organic and diversified vegetable growers[2], cover crops are often chosen and managed for weed control.

The weed suppressive effects of winter rye (*Secale cereale* L.), hairy vetch (*Vicia villosa* L.) and red clover (*Trifolium pratense* L.) cover crops have been well documented[3–8]. Other cover crops, including certain brassica species, have been examined for weed control on a more limited basis. However, there is good reason to consider brassicas as a cover cropping option when weed management is a priority. Members of the *Brassicaceae* family contain glucosinolates—sulfur-containing molecules that are hydrolyzed to form compounds toxic to a variety of soil-borne organisms, including weeds[9]. Laboratory and greenhouse studies suggest that the hydrolysis products of glucosinolates, as well as brassica residues and extracts containing these compounds, are toxic to weeds[10–16], insect pests[17,18] and pathogens[19–21]. In addition, a limited number of field studies have confirmed the ability of brassicas in rotations to suppress weeds[22–24], nematodes[25] and fungal pathogens[26].

These pest-management possibilities, in addition to general benefits of cover cropping, make members of the *Brassicaceae* promising cover crops for use in agronomic and horticultural systems. Several recent reviews have addressed glucosinolate chemistry and the potential use of brassicas for the management of insect pests and plant pathogens[9,27–29]. Here we review the literature, with a focus on the use of brassica cover crops for weed control in agricultural and horticultural production systems.

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Brassica Cover Crops: Unique Characteristics

Members of the *Brassicaceae*, including yellow and white mustards (e.g., *Sinapis alba* L.), canola (*Brassica napus* L.) and rapeseed (also *B. napus* L.), are being used increasingly as cover crops in temperate regions of North America. These species are typically grown for their seeds, which are harvested for oil production, as with canola and rapeseed, or used for condiment production, as with mustard. However, each of these species can also be grown as a short-season cover crop or, if climate allows, as an overwintering cover crop.

Rapid growth and nutrient capture

Both spring- and fall-planted brassica cover crops can rapidly produce biomass. Winter varieties of rapeseed and canola can provide more than 80% ground cover during the winter[30], an important consideration for erosion control. Fall-planted rapeseed cover crops in eastern Washington and southern Idaho yielded 3000–8000 kg dry biomass ha^{-1} by the time they were incorporated the following spring[22,23,30]. In Maine, spring-planted yellow mustard produced 3000–4500 kg dry biomass ha^{-1} 1.5 months after planting (Haramoto, unpublished data). On the other hand, Krishnan et al.[24] reported much lower biomass production (500–1400 kg dry biomass ha^{-1}) in Nebraska for mustards and rapeseed.

Brassicas are also capable of capturing excess nitrate remaining after crop harvest, preventing nitrogen (N) loss from leaching, with overwintering cover crops being more efficient than those that are frost-killed[31–33]. Overwintering rapeseed, forage turnip (*Brassica napus* L.), canola and white mustard were equal to winter wheat (*Triticum aestivum* L.), winter barley (*Hordeum vulgare* L.), winter rye and Italian ryegrass (*Lolium multiflorum* Lam.) in their capture of excess N in the fall[32,33]. The N scavenging in these studies was related to biomass production. Canola and forage turnip cover crops sown in August and incorporated at the end of October were similar to barley in their capacity to capture excess N following sweet corn (*Zea mays* L.) harvest[31]. White mustard planted after sweet corn harvest was able to capture more N than a sudangrass (*Sorghum bicolor* L.) cover crop[33]. As mustards are frost-sensitive, the fate of this captured N then depended on residue management after the cover crop was frost-killed. More N from the mustard biomass was returned to the soil over winter if the residues were incorporated in the fall; whereas spring incorporation of residues led to less N loss. Thus, in addition to providing physical protection, residues left on the soil surface over winter may reduce N leaching. Others have reported N immobilization following incorporation of brassicas[34,35]. Slower release of plant-available N may be beneficial in certain cropping systems as the N is available for the crop instead of weeds that emerge earlier[36]. However, N immobilization may not be desirable for crops with early N demands, making it necessary to consider nutrient management benefits against potential N immobilization.

Biologically active secondary compounds: 'Biofumigants'

All members of the *Brassicaceae* examined to date contain glucosinolates[9]. Glucosinolates consist of a glucose molecule, a sulfur moiety, and a side chain, the composition of which determines their properties. Glucosinolate molecules are not toxic but are enzymatically hydrolyzed to yield a variety of biologically active products, including isothiocyanates, ionic thiocyanates, nitriles, oxazolidinethiones, organic cyanates and epithionitriles[9]. Myrosinase, the enzyme responsible for glucosinolate breakdown, is separated intercellularly from the glucosinolate molecules. Thus, tissue disruption is necessary before biologically active breakdown products are released[9]. In the field, this disruption can be accomplished by mowing, grazing, freezing, tillage or root death.

Mustards, e.g., white and yellow mustards; Indian, brown and Chinese mustards (*Brassica juncea* L.); and black mustard (*Brassica nigra* L.), typically have a high seed glucosinolate content, as evidenced by their biting flavors. In contrast, canola, which has a very low seed glucosinolate content, was derived from cultivars of rapeseed that contained low concentrations of glucosinolates and erucic acid in the seed; these are also referred to as 'double-low' cultivars[37,38]. Canola contains less than 30 µmol of aliphatic glucosinolates g^{-1} of oil, and the oil is less than 2% erucic acid[37]. If the oil contains more of these compounds, it is not classified as canola (Jim Davis, personal communication). Vegetative tissues of canola may contain higher concentrations of these compounds, though typically the glucosinolate content of vegetative tissues is 10% that of the seed (Jim Davis, personal communication). The term 'single-low' refers to rapeseed varieties with a low concentration of erucic acid, below 2% as with canola. Because of early concerns that higher amounts of erucic acid could lead to health problems, low concentrations of this compound determine the suitability of the oil for human consumption, and both canola oil and oil from single-low rapeseed varieties are edible[39,40]. Seed-meal glucosinolate content determines its suitability as a livestock feed supplement, as higher amounts of glucosinolates in feed can lead to goiter in livestock[38–40]. Because of its low glucosinolate content, canola meal can be used for livestock feed. If the glucosinolate content of rapeseed seed meal remains low, it too can be used as a feed supplement.

Profiles of glucosinolate molecules vary between different brassica species[41–43], between individuals of the same species or genotype[30,44,45], and even within different plant tissues of a single individual[46,47]. While different cover crops at particular life stages may be used to manage specific pests[43], complications may arise because the hydrolysis

products of different glucosinolate molecules vary in their toxicity to different organisms[9]. Such targeted pest management may also be complicated by edaphic factors, which can alter the exact profile of hydrolysis products released from glucosinolates. For example, nitrile formation was favored at acidic soil pH, albeit at pH values lower than those typically found in agricultural fields[48,49].

Isothiocyanates and the other glucosinolate derivatives have relatively high vapor pressure and are thoroughly dispersed throughout the surrounding soil, where they may affect soil-borne fungal pathogens, insects and nematodes[50]. Suppression of fungal pathogens by brassica tissues was so promising that one researcher coined the term 'biofumigation', in reference to their effects[20], and the use of incorporated brassica residues has been proposed as an alternative to the use of methyl bromide[51]. Brassica residues inhibit fungal growth and reproduction[20,51,52]; they may also reduce disease pressure in the field[26,53].

The effects of glucosinolates on insect pests have been variable and are complicated by species-specific interactions. Specialist pests may be attracted by glucosinolates and damage from these specialists tends to increase with increasing glucosinolate content of the plant[18,28,29]. Growth rates of generalist insect feeders[17] and feeding by generalist invertebrates and vertebrates[18,54] both declined when the animals were exposed to increasing concentrations of glucosinolates. Incorporation of rapeseed residues before potato (*Solanum tuberosum* L.) cropping reduced Columbia root-knot nematode (*Meloidogyne chitwoodi* Golden et al.) colonization in the zone of residue incorporation for 6 weeks, although nematode damage remained severe enough to cause economic loss[25]. Additions of brassica residues to soil with the root-knot nematode (*Meloidogyne javanica* Treub) reduced the nematode numbers, although the reductions were not correlated with glucosinolate content[55].

Brassica Residues and Allelochemicals: Bioassays in Controlled Environments

Cover crop residues, whether incorporated or left on the soil surface, can affect weed dynamics by reducing or delaying seed germination, reducing establishment and suppressing individual plant growth. Each of these mechanisms can contribute to overall declines in the density and vigor of the weed community[56,57]. Bioassays of isolated glucosinolate hydrolysis products, extracts of brassica residues and brassica residues themselves demonstrate that seed germination, emergence and growth are each adversely affected.

Germination

In purified form, glucosinolate hydrolysis products generally inhibit or delay seed germination. Glucosinolate hydrolysis products likely affect protein synthesis in germinating seeds and emerging seedlings[10]. Allyl isothiocyanate was most effective in suppressing seedling growth if applied directly within 3 days of germination, suggesting that the effect was due to the relatively large amounts of isothiocyanates absorbed compared to the seedling mass, or that one of the first processes in seed germination was inhibited[10].

Glucosinolate hydrolysis products can inhibit germination of dormant and non-dormant seeds[12,15,58,59]. After exposure to methyl isothiocyanate, ungerminated seeds in one experiment were dissected and found to be dead[12]; however, in another experiment, ungerminated seeds exposed to various isothiocyanates remained viable[59]. Germination of redroot pigweed (*Amaranthus retroflexus* L.) and large crabgrass [*Digitaria sanguinalis* (L.) Scop.] seeds buried in mesh bags in field plots was completely inhibited by 2.7 m*M* and 5.4 m*M* methyl isothiocyanate[12]. Various isothiocyanates at 1, 5 and 10 m*M* inhibited germination of soybean (*Glycine max* L.), corn, wheat, rapeseed, dandelion (*Taraxacum officinale* G.H. Weber ex Wiggers), alfalfa (*Medicago sativa* L.) and cucumber (*Cucumis sativus* L.), with varying toxicities of the isothiocyanates to the plant species[42]. For example, benzyl isothiocyanate inhibited germination of dandelion and alfalfa seeds at lower concentrations than the remaining bioassay species. Applications of other isothiocyanates to a number of different species produced similar results (Table 1). Typically, a reduction in seed germination rates was positively correlated with the concentration added, but with a high degree of variability, even in these highly controlled experimental conditions.

Isothiocyanates may also delay germination, causing an increase in the time to 50% germination from 2.7 to 8.5 days for large crabgrass exposed to 1 m*M* methyl isothiocyanate[12]. Higher concentrations of methyl isothiocyanate (2.7 and 5.4 m*M*) applied to field soil suppressed emergence of weeds for up to 7 weeks, while lower concentrations suppressed emergence for shorter periods of time.

In addition to the effects of isolated isothiocyanates noted above, volatile and water-soluble brassica extracts also may inhibit or delay germination. In Petri dish assays, volatile compounds released from black and brown mustard caused 89% and 100% inhibition of lettuce (*Lactuca sativa* L.) seed germination, respectively[13]. Volatiles from these residues, along with those from rapeseed, white mustard and kale (*Brassica oleracea* L.) residues caused an 8–19% inhibition of barnyard grass [*Echinochloa crus-galli* (L.) Beauv.] germination, but had no effect on wheat. Water-soluble extracts from various rapeseed and mustard cultivars failed to inhibit the germination of wheat seeds[11], although similar extracts from rapeseed leaves and stems inhibited and delayed germination of lettuce seeds in another study[60]. Extracts of wild radish (*Raphanus raphanistrum* L.) residues inhibited germination of pitted morning glory (*Ipomoea lacunosa* L.), sicklepod (*Senna obtusifolia* L.), prickly sida (*Sida spinosa* L.) and yellow nutsedge (*Cyperus esculentus* L.)[61]. Volatile and water-soluble extracts from rapeseed meal also inhibited the germination of lettuce seeds[62].

Table 1. Effects of different isothiocyanates on seed germination. The lower value in the concentration range represents either the lowest concentration tested or the maximum concentration at which no effect was noted; the maximum value is the maximum concentration tested.

Isothiocyanate	Concentration range (m*M*)	Species tested[1]	Effect on germination	Reference
Allyl	0.1–0.3	Wheat	3–13% decrease	15
Methyl	0–100	Wheat	No effect to 88% decrease	57
Methyl	0.1–4	Large crabgrass	No effect to 97% decrease	12
Methyl	0.1–4	Dormant large crabgrass	Increase to 95% decrease	12
Methyl	1–10	Scentless mayweed	23–100% decrease	57
Methyl	1–10	Smooth pigweed, barnyard grass, spiny sowthistle	No effect to complete inhibition	57
Methyl	1–10	Blackgrass	No effect to 80% decrease	57
Benzyl	0.2–0.6	Velvetleaf	No effect to complete inhibition	56
Benzyl	0.2–1	Corn	No effect at any concentration	56
Benzyl	0.2–1	Soybean	No effect to 58% decrease	56
Benzyl, butyl, phenyl, methyl, ethyl	0.1–0.3	Wheat	No effect at any concentration	15
2-phenethyl	0.1–0.3	Wheat	8–38% decrease	15

[1] Species tested included: wheat (*Triticum aestivum* L.), large crabgrass [*Digitaria sanguinalis* (L.) Scop.], scentless mayweed (*Matricaria inodora* L.), smooth pigweed (*Amaranthus hybridus* L.), barnyard grass [*Echinochloa crus-galli* (L.) Beauv], spiny sowthistle [*Sonchus asper* (L.) Hill], blackgrass (*Alopecurus myosuroides* Huds.), velvetleaf (*Abutilon theophrasti* Medic.), corn (*Zea mays* L.), and soybean (*Glycine max* L.).

Establishment

Mixed with soil, brassica residues can reduce seedling emergence, a combination of effects on the processes of germination and early seedling growth. Rapeseed residues decreased the number of hairy nightshade (*Solanum sarrachoides* Sendtner), longspine sandbur [*Cenchrus longispinus* (Hack.) Fern.] and hemp sesbania [*Sesbania exaltata* (Raf.) Rybd. Ex A.W. Hill] seedlings that emerged in greenhouse pots[22,42], although velvetleaf (*Abutilon theophrasti* Medicus) emergence was not affected[24]. Similarly, white and brown mustard residues decreased the emergence of kochia [*Kochia scoparia* (L.) Schrad.], shepherd's purse [*Capsella bursa-pastoris* (L.) Medicus.], green foxtail [*Setaria viridis* (L.) Beauv.], redroot pigweed, hemp sesbania and velvetleaf[23,24,42]. Turnip-rape (*Brassica napus* L.) residue decreased the emergence of spiny sowthistle (*Sonchus asper* L.) by over 50%, but actually increased the emergence of smooth pigweed (*Amaranthus hybridus* L.)[59]. Common chickweed [*Stellaria media* (L.) Vill.] emergence was decreased as the amount of rapeseed residue added to pots was increased[23], indicating that incorporating more residue would lead to improved weed control.

Some of the observed between-species variation in brassica residue effects on germination and/or establishment may be due to differences in seed size. Smaller seeds are, in general, more susceptible to residue-mediated stresses, including allelopathy[59,63–65]. Petersen et al.[59], for example, noted that the same concentration of methyl isothiocyanate caused a 79% decrease in germination for spiny sowthistle and only a 5% decrease for wheat, an effect attributed to differences in seed size (0.2 g thousand^{-1} spiny sowthistle seeds compared to 45.3 g thousand^{-1} wheat seeds). However, germination of smooth pigweed and spiny sowthistle, which have similar seed mass (0.5 and 0.2 g thousand^{-1} seeds, respectively), was similarly affected by isolated isothiocyanates, but was affected very differently by turnip-rape residues, as noted above. As this example suggests, efforts to establish a threshold seed size at which inhibition of germination is likely to occur has thus far been unsuccessful[64,66]. Factors other than seed size, including seed morphology[67,68] and biochemical composition[63–64], may also determine a seed's ability to withstand these stresses.

Growth of established seedlings

In laboratory assays, isothiocyanates also inhibit growth of established seedlings. Benzyl isothiocyanate, for example, at 0.4 m*M*, completely suppressed seedling growth and prevented secondary root formation of velvetleaf; half this concentration caused root rot in developing seedlings, while their shoots remained unaffected[58]. Wheat root length, on the other hand, was only slightly reduced by this compound[15]. Similar concentrations of other isothiocyanates, including 2-phenethyl-, allyl- and methyl-isothiocyanate, caused reductions in coleoptile and root elongation of wheat seedlings[15].

Water-soluble extracts from canola root, stem and leaf tissues suppressed the growth of wheat, barley and corn seedlings, even after only one day of incubation[16]. Extracts of canola leaves were the most phytotoxic to the seedlings, causing decreased coleoptile and radicle elongation compared to the control[16]. Similarly, water-soluble extracts from dead black mustard stalks and leaves were effective

in decreasing radicle growth of rigid ryegrass (*Bromus rigidus* Roth.)[69]. Volatile allyl isothiocyanate produced from macerated black mustard tissues also reduced the growth of rigid ryegrass, but tended not to persist in the environment[69]. Extracts of wild radish residues reduced cotton (*Gossypium hirsutum* L.) radicle length by 75%; pitted morning glory radicle length was inhibited by 63%[61].

Seedlings grown in soil with incorporated rapeseed or mustard residues are affected in ways comparable to those exposed to residue extracts. Several similar experiments have demonstrated that kochia, shepherd's purse, green foxtail, hairy nightshade, redroot pigweed and velvetleaf seedling biomass was decreased when grown with mustard or rapeseed residues (0.04–0.05 g residue g^{-1} soil) compared to those grown without[22–24]. For example, when compared to potato residue, rapeseed residue decreased hairy nightshade and longspine sandbur biomass by 82 and 83%, respectively after 3 weeks[22]. Likewise, fresh white mustard residue reduced hairy nightshade and green foxtail seedling biomass by 83% and 70%, respectively, compared to seedlings grown without brassica residues[22]. Despite these generally comparable results, other studies suggest that mustard residues may be more effective in suppressing seedling growth than rapeseed, especially the growth of smaller-seeded species such as kochia and shepherd's purse[23]. Unexpectedly, the growth of wheat seedlings was actually increased by similar amounts of mustard and rapeseed residues when compared to soil alone, a result that is potentially attributable to the larger seedling size of wheat[42].

Effects of Brassica Rotation Crops on Weeds

Despite the generally promising laboratory, greenhouse and field results discussed above, the issue of whether brassica cover crops are allelopathic and can consistently provide weed control remains contentious. Differentiation between multiple 'residue-mediated' effects of cover crop residues, whether incorporated or left on the soil surface, and clear allelopathic mechanisms is difficult[70]. These residue-mediated effects may result from physical, biological or chemical changes to the soil environment, each of which may impact weeds[65]. Physical effects may result from changes to soil temperature or light penetration to the soil surface, each of which may impact weed seed germination[6]. These effects may be particularly pronounced when cover crop residues remain on the soil surface. An example of biological residue-mediated effects includes cover crop residues providing a habitat for seed predators or decay agents[57]. In addition to allelopathy, chemical residue-mediated effects may include nutrient sequestration or release, particularly that of nitrogen in the case of leguminous cover crops[36]. Regardless of the exact mechanism, in several natural and manipulated ecosystems, brassicas have had a negative impact on surrounding plants, or following crops. For example, historically, dyer's woad (*Isatis tinctoria* L.) cultivation was restricted because of harmful effects on following crops[71]; others noted that reduced grass and clover yields were common on fields that previously grew brassicas[72]. Yield loss in flax (*Linum usitatissimum* L.) was greater in crops containing brassicaceous weeds than in flax infested by other types of weeds[73]. Annual grasslands in southern California contain monospecific stands of black mustard that yearly perpetuate themselves[69]. Studies of this system revealed that neither soil nor edaphic factors were responsible for the exclusion of grasses from these areas; likewise, preferential animal grazing and competition were ruled out. However, water-soluble compounds leached from the dead mustard residues during the rainy season inhibited the germination of rigid ryegrass and reduced its growth, supporting the conclusion that allelochemicals leached from the brassica tissues were responsible for excluding the grasses and maintaining the monospecific black mustard stands[69].

Early in the culture of rapeseed as an oilseed crop, growers reported negative effects of rapeseed residues on subsequent cereal crops[74]. Heavy rapeseed-residue-containing stubble and plant debris, as would be left in a combine windrow, decreased the dry biomass and height of wheat, barley and oats (*Avena sativa* L.) compared to a light rapeseed residue composed of stubble only[74]. Density of the cereals was similar in the two residue treatments, indicating that the abundant residues were stunting the growth of established plants[74]. Interestingly, severity of root rot in the cereals was lower following the heavy residue, consistent with reports that brassica residues may help manage fungal pathogens[74].

Rapeseed windrows also contained viable seed, lost through the combining process, that could germinate as volunteer plants. Simulating this, Vera et al.[67] found that incorporated rapeseed and mustard seedlings reduced the establishment, delayed the development and reduced the seed yield of the subsequent crops. Oilseeds, including rapeseed and flax, were more sensitive than the cereals tested, including barley and wheat; oat growth was not affected at all[67]. Both mustard and rapeseed seedlings caused similar decreases in growth, despite presumable differences in glucosinolate content, which was not measured[67].

In other examples, nitrogen immobilization has been suggested as the cause of reduced plant growth following brassicas[68,75]. Growth of alfalfa, a legume, was not affected by the incorporation of wheat or rapeseed residues, while barley and bromegrass (*Bromus inermis* Leyss) showed signs of nitrogen deficiency[75]. However, Bell and Muller[69] found no differences in soil nitrogen content between areas dominated by black mustard and areas dominated by annual grasses. Similarly, addition of nitrogen to wheat grown after different brassica species and cultivars did not change the effects of the residues on wheat growth or yield[11].

Effects of Brassica Cover Crops on Weeds

Rotation effects of brassicas have led to investigations on their use as cover crops, grown without harvesting of the seed, for weed control. In south-central Washington, where fall-planted rapeseed will typically overwinter, the effects of rapeseed residue on weeds in a subsequent potato crop was compared to sudangrass residue and a fallow treatment[22]. Fall-planted rapeseed residues were incorporated in the spring, while sudangrass residues were incorporated the previous fall after they were frost-killed; potatoes were then planted into these residues. In the subsequent potato crops, mid-season weed density following rapeseed was decreased by 73–85% relative to weed density following fallow and sudangrass, respectively, in the 2 years of the study; however, these mid-season weed densities were extremely low ($<1\ m^{-2}$). At the end of the season, weed biomass was decreased by 50–97% by rapeseed compared to fallow and sudangrass, respectively. Potato yield was greater following rapeseed than following fallow in both years, indicating that the potato plants were not harmed by the residues.

The effects of fall-planted brassicas on weeds in green pea (*Pisum sativum* L.) were also examined in northwestern Washington[23]. In this study, brassicas included rapeseed and white mustard; rapeseed successfully overwintered in both years, while white mustard was winter-killed in 1 year. Weed density at 30 days after planting was lower following rapeseed and white mustard than following wheat, although weed biomass at pea harvest was similar following all cover crops. Rapeseed residue also consistently decreased pea density and pea yield, effects that were not observed following white mustard. Other field studies including green pea reported a reduction in establishment following both rapeseed[76] and white mustard[26].

Spring-planted mustards can be incorporated into rotations before a cash crop, or planted in succession in fallowed fields. Krishnan et al.[24], at two sites in eastern Nebraska, planted soybean into residues of spring-planted rapeseed, two varieties of white mustard, and brown mustard. Weed biomass, measured at 4 and 6 weeks after soybean emergence, was lower following these cover crops at one location, but not at another. The weed control from these brassica residues was not agronomically sufficient, however, as both locations suffered yield loss following all cover crops if herbicides were not applied. Soybean yields were similar for all cover crops and a fallow treatment, suggesting that the brassica residues did not harm the soybean plants.

Field studies testing the effects of spring-planted brassica residues on weed and crop emergence and growth were recently conducted in central Maine[66]. Sixteen bioassay species, including both crops and weeds, were planted into fallow plots and plots that grew and received incorporated residues of three brassica cover crops—rapeseed, canola and yellow mustard—and three non-brassica cover crops—buckwheat (*Fagopyrum esculentum* Moench.), oats and crimson clover (*Trifolium incarnatum* L.). Averaged over bioassay species, all cover crop residues decreased seedling emergence compared to fallow but, unexpectedly, there were no differences in emergence detected following the brassica cover crops and non-brassica cover crops which lacked glucosinolates, even for species with smaller seeds (Fig. 1). In another experiment, green bean (*Phaseolus vulgaris* L.), redroot pigweed and a mixture of the two species were planted into fallow plots and plots that grew and received incorporated residues of canola and yellow mustard. Although the biomass values of both green bean and redroot pigweed were often lower following the brassica cover crops, and lowest following the high-glucosinolate mustard, differences were not significant (Fig. 2). Competition reduced green bean and redroot pigweed height and biomass, but interspecific interference was unaffected by the incorporated brassica residues. Similarly, marketable green bean yield was lower in plots containing redroot pigweed than in plots with green bean grown alone, but incorporated brassica residues did not mediate the competitive effect. These results suggest that the observed weed suppression by brassica cover crops in the field[22–24], when compared to soil without residues, is likely related to their effects on establishment but not on

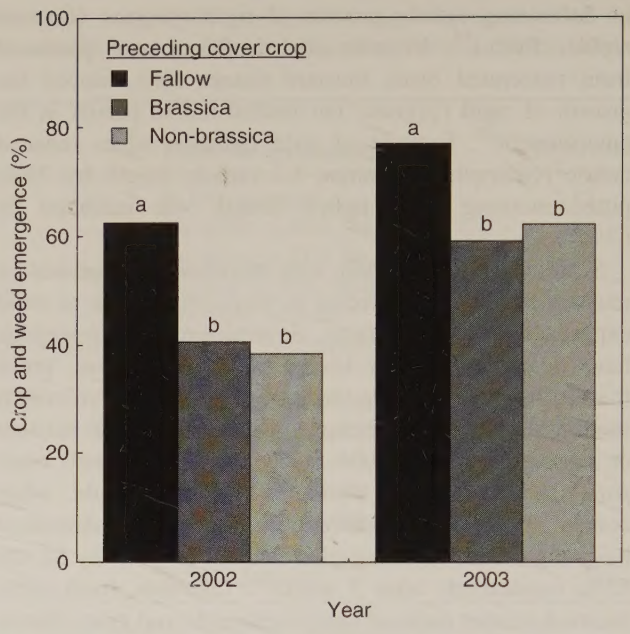

Figure 1. Effect of incorporated cover crop residues on mean emergence of 11 crop and weed species in 2002 and 15 in 2003. Based on analysis of variance of results, data were averaged over the crop and weed species. Single degree of freedom contrasts ($\alpha = 0.05$) compared emergence following no cover crop (fallow, $n = 44$ in 2002 and $n = 60$ in 2003), to emergence following incorporation of brassica (yellow mustard, spring canola and winter rapeseed; $n = 131$ in 2002 and $n = 176$ in 2003) and non-brassica (buckwheat, oat and crimson clover; $n = 131$ in 2002 and $n = 177$ in 2003) cover crops[66]. Within each year, means with the same lower-case letter were not significantly different ($P > 0.05$).

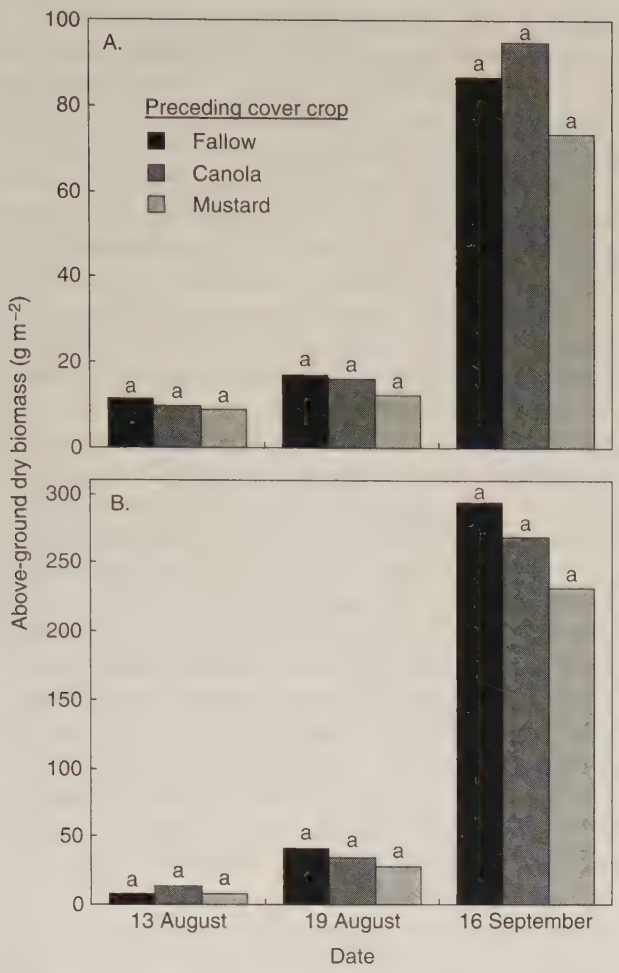

Figure 2. Effect of incorporated low-glucosinolate (canola) and high-glucosinolate (mustard) brassica cover crop residues on above-ground dry biomass of green bean (A) and redroot pigweed (B) subsequently grown in a mixture at fixed densities in 2002; results were similar in 2003. Within each harvest date, means with the same lower-case letter were not significantly different ($P > 0.05$)[66].

the growth of established individuals. The similar effects of the brassica and non-brassica residues on establishment contradict results from several other field studies, which suggest that the impacts of brassicas on weed suppression are greater than those provided by other cover crops[22,23]. These discrepancies highlight the variable nature of residue-mediated effects and emphasize the need to consider the complex relationships among management, species (cover crops, weeds and crops) and edaphic conditions.

Management Strategies and Considerations

Effects of environment and growth stage on glucosinolate production

Some brassicas, including canola, are selected to have low concentrations of glucosinolates in their seeds, and generally have lower concentrations in the vegetative tissue as well[46,77,78]. However, environmental and soil characteristics, as well as management practices, may produce plants with higher and more variable levels of glucosinolates[45,46,79]. A comparison of single-low and double-low rapeseed cultivars found that stems of one double-low cultivar contained a glucosinolate concentration similar to that of the single-low cultivar—over twice the concentration found in the other double-low cultivars[46].

Fertilization with nitrogen and phosphorus increases brassica biomass production and may also increase glucosinolate production[79]. Phosphorus fertilization (60 kg P_2O_5 ha^{-1}) and high levels of nitrogen (132 kg N ha^{-1}) increased the glucosinolate content of a variety of forage brassicas by an average of 26%; the same amount of nitrogen at lower phosphorus levels did not affect glucosinolate production[79]. Both fertilization and drought conditions before or after flowering can lead to large increases in the concentration of glucosinolates in rapeseed seed[78].

Plant growth stage also affects glucosinolate content. Glucosinolate concentrations of brassica tissues usually decrease as the seeds germinate and seedlings grow[77]. However, plant biomass increases rapidly during this time, leading to a maximal glucosinolate *content* (the product of concentration and biomass) in the whole plant before flowering[43,46]. Not until glucosinolate concentrations were expressed on a per plant basis, rather than per unit biomass, was it realized that glucosinolates were being diluted by increasing biomass[71,80].

Growers seeking to use brassica cover crops for weed suppression would be most interested in the glucosinolate content per unit area. Maximal glucosinolate content for the entire plant typically occurs at maturity[46,77], but the plants are generally incorporated prior to this stage, to avoid potential problems with subsequent volunteer seedlings. Glucosinolate content of the vegetative tissues is maximal prior to flowering[43,46], although overall plant biomass at this stage is still relatively low. Thus, growers face a trade-off—incorporate smaller amounts of biomass with the highest glucosinolate content, or wait until flowering has progressed to incorporate more biomass with less glucosinolates. The particular goals of the farmer would aid in making this decision.

Types of effective glucosinolates

Different brassicas have different glucosinolate profiles[30,41–43], which may contribute to the conflicting results of some studies, as different glucosinolate hydrolysis products may have different effects on seed germination and seedling growth (Table 1). In addition, not all brassicas release isothiocyanates; the predominate volatiles released from leaves of certain turnip and rapeseed varieties were the fatty acid derivatives, *cis*-3-hexen-1-ol and *cis*-3-hexen-1-yl acetate[42]. Other studies have identified *trans*-β-ocimene as the dominant volatile in certain Indian mustards, and verbenone as the dominant volatile in black

mustard[81]. Effects of these secondary compounds on seedling germination and growth are largely unknown[81].

Both volatile and water-soluble compounds have been implicated in suppressing seed germination[60], although hydrolyzing brassica tissues is sufficient to remove volatile compounds. Water-soluble compounds from hydrolyzed leaf and stem tissue of rapeseed completely inhibited the germination of lettuce seeds, while water-soluble root extracts from the same hydrolyzed tissues caused only a delay in germination[60]. Only volatiles from intact tissues affected germination, causing a delay, as well as a reduction in lettuce seed germination[60]. Under field conditions, volatiles from brassica residues are extremely short-lived (see below) and water-soluble compounds leached from the residues would likely have the largest impact on germinating seeds.

Limited soil life of glucosinolate hydrolysis products

Glucosinolate hydrolysis products tend to be very ephemeral and do not persist in the soil environment[50,59,69]. After incorporation of brassica residues, release of isothiocyanates is rapid, with concentrations dropping to less than half of the maximum by 72 h[50]. When isothiocyanates are applied directly, as opposed to being applied in glucosinolate form or in residues, the disappearance is even more rapid. For example, the half-life of 2-phenylethyl isothiocyanate applied to soil was approximately 1 h; it was completely undetectable after 91 h[82]. Morra and Kirkegaard[50] measured isothiocynates in soil 24 h after the incorporation of Indian mustard or rapeseed residues. The Indian mustard plots averaged 1.2 nmol isothiocyanate g^{-1} soil, while plots with incorporated rapeseed residue averaged 0.8 nmol isothiocyanate g^{-1} soil, concentrations similar to those found by Gardiner et al.[83] following incorporation of rapeseed residues. However, it is notable that these concentrations are more than an order of magnitude less than those found to inhibit seed germination (Table 1) and seedling growth in laboratory settings[12,15,58,59].

The low concentrations of isothiocyanates found in the soil following incorporation of brassica residues are partially due to the low release efficiency of biologically active breakdown products from glucosinolates. For example, soil concentration of isothiocyanates represented only 0.1–1.0% of the glucosinolate pool following incorporation of Indian mustard and rapeseed residues[50,84]. Other studies have shown similarly low conversion rates of glucosinolates to isothiocyanates and other hydrolysis products[83,85,86]. These studies suggest that the limiting factor in determining isothiocyanate evolution into soil is not the glucosinolate content of the plant, but release efficiency of the hydrolysis products. Practices that further disrupt plant tissue at, or before, incorporation may increase the release of isothiocyanates. Morra and Kirkegaard[50] found that freezing residues caused more cellular disruption and led to a greater release efficiency of isothiocyanates; frozen leaf discs of Indian mustard released 39 nmol isothiocyanates g^{-1} soil in a moderately dry soil. Release of isothiocyanates from these frozen leaf discs was greater in waterlogged soils, with a concentration of 75 nmol isothiocyanates g^{-1} soil. However, release of isothiocyanates does not ensure bioavailability. Glucosinolate hydrolysis products released from macerated tissue may react with organic matter in the tissue itself and may not be released into the environment[87]. Soil characteristics, particularly organic matter and clay content, also affect both the types of compounds released upon glucosinolate hydrolysis, but also, perhaps more importantly, on the adsorption of these compounds to soil particles[87].

Release of glucosinolate hydrolysis products may occur rapidly following incorporation of residues; alternatively, they may be slowly exuded from roots of living plants or leached from dropped leaves on the soil surface. Dyer's woad released indolyl glucosinolate compounds from its roots[71]; canola released 2-phenylethyl isothiocyanate into its rhizosphere[82]. Soil sampled from pots containing a low-glucosinolate rapeseed cultivar contained 24 ng allyl isothiocyanate g^{-1} soil, while soil in pots containing wild-type rapeseed contained 60 ng allyl isothiocyanate g^{-1} soil[70]. Because the soil was sampled without incorporated plant residues, isothiocyanate was presumably released from the growing roots. The slow and steady release of isothiocyanates may keep soil concentrations at levels effective for suppressing pathogens and reducing seed germination.

Effects on beneficial organisms

Nitrifying bacteria, rhizobacteria and mycorrhizae are often desirable in agricultural soils, especially those in systems with reduced external inputs. Plant secondary compounds that harm fungal pathogens and reduce seed germination might also be expected to harm the organisms that are beneficial, and often essential, to healthy agricultural soils. Daily applications of low concentrations (<4 n*M*) of 2-phenylethyl isothiocyanate were sufficient to change the active portion of the soil microbial community composed of bacteria and eukaryotes[82]. These results indicate that brassica residues could affect critical microbial processes, including nitrification, nitrogen fixation and mycorrhizal symbioses.

Nitrogen mineralization from brassica residues is slower than predicted by their C:N ratio, suggesting that glucosinolate hydrolysis products inhibit the actions of soil microbes involved in nitrogen cycling[34]. Populations of both ammonium-oxidizing and nitrite-oxidizing bacteria were adversely affected by applications of isothiocyanates, with soil- and isothiocyanate-specific effects on growth rate and population levels[88]. Nitrification capacity was reduced by 35–65% following 10 µg applications of different isothiocyanates to 1 g of soil[88], while addition of 0.5 µg of 2-propenyl isothiocyanate g^{-1} dry soil was sufficient to completely inhibit nitrification[89]. This latter concentration is similar to those that inhibited seed germination and seedling growth (Table 1), but still higher than that found in

the soil following residue incorporation[50]. Isothiocyanates also acted synergistically with volatile sulfur compounds (including dimethyl sulfide) to cause greater inhibition of nitrification[88].

Compounds harmful to microbes may also affect beneficial rhizobacteria (*Rhizobium* spp.) that form root nodules on legumes, assimilating atmospheric nitrogen in the well-known symbiotic association. For example, nodulation of green peas following incorporated white mustard residue was reduced compared to those following fallow[26]. As soil nitrogen concentrations were not reported, these observational differences cannot be attributed solely to the presence of white mustard residues. However, Scott and Knudsen[76] found that green peas grown in soil with incorporated rapeseed residues had similar numbers of nodules to those grown in soil with no residues, and that carbon utilization was similar between rhizobacteria from these two groups. Rhizobacteria isolated from green pea plants grown in soil with rapeseed residues were similar to those isolated from soil without residue[76]. Adverse affects on pea growth, including reduced germination, poor root development and shorter plants, were noted in both of these experiments, as well as by other researchers[90].

Mycorrhizae are very important for healthy plant growth in agroecosystems, although plants in the *Brassicaceae* do not form mycorrhizal associations[91]. Despite the potent anti-fungal properties of glucosinolate hydrolysis products, there does not seem to be a consistent effect of brassicas on mycorrhizal spore germination, or the mycorrhizal infection of nearby plants. Compared to those near tomato (*Lycopersicon esculentum* Mill.) and tobacco (*Nicotiana tabacum* L.) roots, vesicular arbuscular mycorrhizal (VAM) hyphae near brassica roots had fewer germ tube branches and fewer hyphal tufts, suggesting that they may be harmed by compounds leaching from brassica roots[92]. Onions (*Allium cepa* L.) grown in the same pot as swede (*Brassica napus* L.) had a smaller percentage of root length infected by mycorrhizae[93]. This evidence conflicts with other studies that have demonstrated that mycorrhizal plants grown with brassicas are not affected[94]. In addition, there is typically no effect on mycorrhizal infection by brassicas in rotation with mycorrhizal plants[92,94–97]. While isothiocyanates are capable of killing certain species of VAM fungi, other VAM species may have the capacity to detoxify glucosinolates, as these fungi differ widely in their response to anti-fungal compounds[92]. Other non-brassicaceous plants that release glucosinolates from their roots, including papaya (*Carica papaya* L.) and nasturtium cress (*Tropaeolum* spp.), do form mycorrhizal associations, suggesting that the glucosinolates themselves are not toxic to all mycorrhizae and that other mechanisms prevent brassicas from forming this association[91].

Conclusions

Brassica cover crops have been suggested as a possible solution to many pest problems in agricultural and horticultural systems. Considerable evidence of the negative effects of brassica residues on seed germination and growth supports the idea that brassica cover crops can be used as 'biofumigants'. Suppression of weed density and weed biomass in field experiments further bolsters this idea. However, mechanisms behind this observed effect on weed communities in different crops remain unknown, as our recent field studies in Maine failed to find support for hypotheses that brassica residues would: (1) provide additional suppression of seedling recruitment beyond that provided by other non-brassicaceous cover crops; and (2) reduce the growth of established plants. Clearly, many factors influence the pest-management potential of brassicas, and earlier suggestions that brassica cover-cropping systems may be 'tailor-made' to specific pest problems may prove to be both overly optimistic and too difficult to be practical to growers. Brassica cover crops do have a place in low-input farming systems as substitutes for other, more conventional cover crops. Their ability to suppress soil-borne disease pathogens may prove extremely beneficial. Although their effects on beneficial mycorrhizae, rhizobia and free-living nitrogen-fixing bacteria must be considered, evidence suggests that brassica residues will not cause significant harm to these beneficial biota. As with most tactics utilized in low-input farming systems, multiple benefits may result from their use, but it remains important to use multiple tactics for a strong program of weed management.

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Increasing the effectiveness of technology transfer for conservation cropping systems through research and field design

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Abstract

A survey was conducted in 2002 to measure the success of technology transfered to growers (i.e., changes in attitudes and behaviors) from a long-term, large-scale, integrated cropping systems experiment called the Ralston Project, near Ralston, Washington, USA. Non-irrigated, cereal and oilseed growers who participated in biennial field tours (1996–2000) were mailed a self-administered questionnaire, which asked about: (1) their interest, use and adoption of technology developed or demonstrated in the project; (2) their opinions about the project's collaborators, planning and design; and (3) their overall impressions of the project. One hundred and one eligible growers responded to the questionnaire, for a 55% overall response rate and a 62% completion rate. Survey results confirmed that the Ralston Project field tours were a successful means of technology transfer among participants. Seventy-seven percent of growers found one or more project technologies particularly useful to their own production operation(s). More than 60% conducted independent trials with one or more technologies, with 50% of these trials resulting in permanent adoptions. The project's planning and design had a more positive effect on growers' opinion of the project than the type of collaborations and sources of funding. Specific strategies that had a substantially positive effect on growers' opinions included: (1) the project's 'whole system' treatment design; (2) use of large plots to accommodate field-sized equipment; and (3) collaboration among scientific disciplines and with local growers. Seven variables known to influence the adoption of innovation were also tested against growers' decisions to try any of the project's technology in their own farm operations. Personal character variables influenced individuals' decisions to try project technology more so than environmental conditions. Level of education, previous adoption behavior and average annual rainfall significantly influenced growers' behavior ($P < 0.05$). Our survey population consisted of early users of conservation-based farming technology, primarily innovators and early adopters. The Ralston Project made the greatest impact on current adopters and users of conservation-based farming technology. Interest among non-users was also high enough to suggest that the Ralston Project contributed positively to the diffusion of conservation cropping systems and associated technology into the greater grower community. We discovered from this survey that the planning and execution of field research plays a significant and influential role in transferring more complex, and perhaps high-risk, conservation-based farm technology. By understanding how research and field design affect different user groups within the grower community, professionals can identify appropriate strategies to expand interest beyond their primary target audience and influence attitudes and behaviors that facilitate widespread adoption.

Key words: diffusion, adoption, impact, conservation cropping systems, technology transfer, Ralston Project

Introduction

Agricultural research for commercial food production has improved the health and wealth of individuals in many countries around the world, but research and development's (R&D's) yield-enhancing technologies have also come with severe environmental consequences. Soil erosion and invasive species plague food systems worldwide. Current conditions present today's researchers with a tougher challenge of balancing economic, agronomic and environmental

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priorities. Innovative trends in crop research are rapidly spreading within US agriculture to meet this challenge of developing profitable and agronomically feasible conservation cropping systems. These trends include long-term, large-scale, multidisciplinary and systems-level field experiments, along with an increased emphasis on grower participation. In spite of the known environmental and social benefits of conservation cropping systems (e.g., no-till), long-term, conservation crop research continues to struggle for funding sources against more traditional, short-term, maximum-yield oriented research.

The environmental objectives of conservation crop research revolve mainly around lowering the intensity of synthetic inputs and reducing activities that instigate topsoil loss. Such objectives are not always conducive to the quick turnaround of data or maximized yield and profit margins. In addition, the complexity of such crop systems does not lend itself to immediate, or even complete, adoption by end-users. In the absence of more immediate measures for validating time and effort spent, researchers can measure the social impact of their technology transfer activities to establish their research's worth to science, industry and society. Case evaluation studies are an effective means of documenting the impact of research on growers. Impact can be estimated by measuring changes in growers' attitudes and behaviors towards technology, treatments or other points of interest in the research project. An evaluation study may provide researchers with a tool powerful enough to: (1) justify their expenditures; (2) reaffirm the outward contributions of their research; (3) increase current spheres of influence; and (4) enhance their effectiveness in technology transfer.

Field researchers in the inland Northwest (eastern Washington, northeastern Oregon, northern Idaho) have increasingly used innovative research strategies to develop conservation-based farming alternatives to a traditional, monocrop wheat/fallow system, and to refine best management practices for more complex farming technologies (e.g., no-till drill). The impacts of recently developed technologies and field research methodologies on the research community are well-documented[1–3]. However, the impact of individual field studies on growers has not been formally established. We evaluated an innovative, conservation-based, field research study in 2002 called the 'Ralston Project' to find out how growers responded to what they saw and learned at field tours. In other words, we measured the changes in growers' attitudes and behaviors as a result of this particular kind of research study.

The Diffusion of Research Innovation: A Theoretical Framework

Developing new farm technology, such as a no-till drill or optimal seeding rate, represents one part of applied field research. Another important task is the transfer of new ideas and technology beyond the scientific community. More and more, funding agencies require researchers to incorporate technology transfer activities into their research goals and experimental planning. Technology transfer activities range from writing journal articles and technical manuals to conducting field tours or plot demonstrations, and, more recently, constructing Internet websites. New ideas and technology, whatever their benefit, do not always travel far from the point of origin. The rate and extent to which any new idea or technology (i.e., innovation) from research travels through a community depends a great deal on factors external to the research. For this reason, it is necessary for researchers to grasp how society and environment influence their R&D, transfer activities and spheres of influence.

Technology transfer comprises one aspect of a larger sociological process called the diffusion of innovation. Diffusion is the 'process in which an innovation is communicated through certain channels over time among the members of a social system'[4]. The diffusion–adoption model[4,5] provides a comprehensive analysis of factors influencing adoption, and is perhaps the most widely known explanation for how and why innovations become accepted/rejected within a community. For example, a grower's location and formal education will often alter his/her level of risk tolerance[5,6], which will vary the perceived utility or value of a new farming practice. The diffusion–adoption model accounts for these social and environmental dynamics that surround an innovation and affect its rate, direction and extent of diffusion.

The acceptance and/or adoption of a new idea, technique or technology can vary considerably among innovations and communities. In the USA, hybrid seed corn reached nearly 100% adoption by Iowa farmers within 15 years of introduction[5], whereas adoption of the no-till drill is still low after 30 years of crop R&D[7]. Diffusion timelines are determined by the rate at which individuals within a community work through the decision-making process[6] and are influenced by: (1) the characteristics of the innovation: relative advantage, compatibility, complexity, trialability, observability; (2) the context of its introduction (e.g., prevailing regulations and markets); and (3) the characteristics of individuals (e.g., education, age, land ownership)[7]. For example, a grower's mechanical skill may increase his/her chances of adopting an intricate, conservation-based crop program, but only if favorable niche markets exist to offer a premium price for his/her 'eco-friendly' product. Researchers can affect diffusion timelines by understanding the degree of influence of these three major conditions on a particular innovation. Although the innovation itself is fairly static, the favorability of its characteristics (listed above) can change by how it was incorporated within an experiment. For example, using a no-till drill as part of an integrated crop/weed competition study might increase a growers' interest over a basic tillage demonstration, because the grower is able to see how the drill affects other elements that determine crop performance. An innovation that can be broken down or tried out on a partial basis also increases the probability of use and adoption[5]. Still, the

favorability of an innovation is greatly influenced by the characteristics of individuals that comprise the community or group of interest.

Personal characteristics form the 'viewing lens' through which an innovation is judged. Character traits of the individual have the potential to override seemingly negative points and overcome barriers to adopting the innovation. Collectively, these traits segregate individuals of a community into categories according to their likeliness to adopt. Adopter categories, which we'll refer to as user groups, are generally divided among five behavior types—innovators, early adopters, early majority, late majority and laggards[5]. The group into which an individual falls is relative to the innovation of interest. Among these five groups, innovators and early adopters are generally more curious, more formally educated, able to process abstract ideas and accept a higher level of risk than individuals in other groups. Innovators possess a more daring nature that allows them to try new ideas with little regard to public opinion, while early adopters are more selective in their experimentation and have a higher level of community influence. For these reasons, both innovators and early adopters are important target groups for research and extension. However, the historical USA extension model has drastically underutilized the assets of all user groups[8,9] in formulating technology transfer strategies for widespread diffusion of research.

Rural America's increased mobility and access to information has significantly diminished the passivity of growers[10]. Growers are steadily becoming more active participants in research as well as the developers of conservation technology. The traditional model of extension has yet to fully adjust to current social conditions[10], where growers are more independently informed about research and industry and have a higher degree of influence over research[8,9] and other growers[11]. Extension's traditional approach to technology transfer can actually cripple diffusion by stratifying relations among developers and users[9,12] of technology, underutilizing available resources[8,9,12], and limiting acceptable avenues for idea exchange[9,11,12].

A prime example of this dilemma occurred during the Integrated Pest Management Project (1985–1994) in Pullman, Washington, USA[13]. At the conclusion of the project, several growers voiced concern over the lack of research/grower interaction and government research agency's exclusive use of research farms to conduct experiments. Their dissatisfaction culminated into accusations that scientists did not share research results. A communication gap such as this may have discredited the research among local growers and crippled the diffusion[5] of even its successful production strategies. As more individuals worldwide move into the 'information era', it becomes more important for research organizations to reflect on how they view and utilize growers in the promotion of R&D. In 1995, several local researchers attempted to address this issue by constructing a full-scale, collaborative experiment based on the suggestions and concerns of local growers.

The Ralston Project: Case Evaluation Study

Dryland (i.e., non-irrigated) crop producers on the Columbia Plateau and Columbia Basin regions of the inland Northwest struggle with a wide range of agronomic concerns, given the area's low annual rainfall (150–460 mm), erratic winds, highly variable topography and fine-textured soils. Soil erosion from wind alone causes soil losses of >4.5 Mg $ha^{-1} yr^{-1}$ on approximately 1 Mha of cropland each spring[14]. A significant portion of this erosion is attributed to growers' traditional use of the winter wheat–fallow system. The research and adoption of this rotation has persisted over much of the past century because of its low risk of crop failure and cost-effective control of pests and storage of soil moisture[15]. Yet, the frequency of exposed topsoil from tillage practices in crop and fallow management has cumulatively jeopardized environmental and agronomic sustainability[1] and public health and safety[16].

The No-till Integrated Spring Cropping Systems Research Project, better known as the 'Ralston Project' was initiated on private land in the fall of 1995 near Ralston, Washington, USA, to examine the economic, environmental and agronomic feasibility of reduced tillage and continuous spring cropping systems in a low rainfall regime[17]. New crop systems were developed to either replace or supplement the traditional winter wheat–fallow system. The focus of selected treatments reflected a compromise between scientists' interests and growers' needs expressed during planning meetings, namely: (1) using reduced or no-till drills for simultaneous planting and fertilizing; (2) retaining crop stubble for erosion control and soil moisture retention; (3) managing crop stubble for pest/disease control; (4) evaluating crop varieties for pest/disease resistance; (5) using spring crop rotations in lieu of fallow; (6) spring cropping for pest/disease control; and (7) determining the economics for each treatment rotation. A greatly enlarged plot size was also proposed, extending it beyond the typical plot measure of 3 m × 9 or 12 m, in order to accommodate for 'real world' field variation, commercial-size machinery and scientific validation.

The experimental design consisted of four replications of four different crop systems on 152 m × 9 m (500 ft × 30 ft) plots set over two adjacent fields[18]. This arrangement allowed each crop within each rotation (treatment system) to be grown every year. Treatment rotations consisted of: (1) reduced-till winter wheat/fallow; (2) no-till soft white spring wheat/chemical fallow; (3) no-till continuous hard red spring wheat; and (4) no-till hard red spring wheat/spring barley. Procedures and equipment used in the management of each treatment system incorporated the best management prescriptions (BMPs) of previous single-component/disciplinary studies and several short-term side experiments conducted in conjunction with the Ralston

Project. From 1996 to 2000, scientists from ten disciplines monitored and evaluated treatments annually for: (1) weed population dynamics; (2) soil fertility; (3) variety/pest resistance; (4) performance of tillage operations; (5) soil moisture and erosion control; (6) pest incidence; (7) grain yield and quality; and (8) economic profitability and risk. Cooperating researchers held half-day, public field tours at the project site every other year to report their findings, demonstrate new equipment, consult with other scientists, and engage in discussion with growers.

At the conclusion of the 5 years, collaborators and associated scientists agreed that the unusually large design and integrated focus of the project positively impacted the quantity and quality of field data collected. The project's integrated crop management (ICM) approach, through its 'whole crop system' simulations, also served to benefit technology transfer and further R&D[12]. Some collaborators felt that the major benefit to growers was the immediate application of project technology to their production operations because each technology was already tested within the larger context of the cropping system. This position was supported by previous studies in other agricultural centers, which found that local relevance, adaptability and the applicability of research to growers improved their acceptance of research[19,20] and influenced adoption[7], particularly among complex and conservation-based farming technology. The question of whether or not the Ralston Project impacted local growers in ways that encouraged the diffusion of its technology has remained speculative and undocumented. We chose to evaluate and document the impact of this specific project because it represented the wheat–fallow region's first and longest-running project that combined multiple design elements previously documented to increase grower receptivity to research[12,13,19], specifically long-term, large-scale, multi-/interdisciplinary, multi-agency, grower-directed, integrated and crop system-level research.

Study Objectives

In our survey study, we wanted to find out if and how the Ralston Project had an impact on technology transfer of conservation cropping systems and associated technology. In other words, did growers change their attitudes or behaviors in response to what they saw or learnt at Ralston Project field tours? What specifically influenced these changes? We addressed this objective by evaluating the Ralston Project, via survey, based on the following research questions:

1. Who were the growers that attended the Ralston Project field tours?
2. Did growers find the project useful in addressing their production concerns?
3. To what extent did growers change their behavior by using practices/technologies seen in the Ralston Project?
4. Was there anything in particular that increased their opinion about the project as a whole?
5. What variables most influenced the growers' decision to try project technologies?

Methods

One major avenue for technology transfer is the research field tour. During field tours, growers have direct contact with new and developing technology. It also provides researchers with a readily available population for surveying. We evaluated the Ralston Project by surveying growers who attended the project's biennial field tours in at least one of the following years: 1996, 1998 and 2000. Registration rosters, furnished by Washington State University Cooperative Extension, afforded us the opportunity to locate growers who had direct contact with the Ralston Project, to find out what information and technology was taken directly from the project and how it was being used.

Those attending Ralston Project field tours included farming families, agribusiness representatives, federal and state agency representatives, academic and agency research personnel, and local extension professionals. Individuals from the above list who were easily identified in professions other than farming were removed from survey. All other individuals were contacted for surveying, but we restricted survey eligibility to dryland cereal and oilseed growers who considered themselves the primary production decision-maker for their operation(s).

Eligible growers were surveyed via mail (post) using a self-administered questionnaire. This method was determined to be the most effective means of collecting data among a population widely distributed across several states. In addition, the high volume of farming activity during our survey timeline significantly restricted the availability of individuals for telephone or personal interviews. The mail survey allowed respondents more flexibility in how and when they completed the questionnaire, and gave them the opportunity to change or expand upon answers after further reflection. Only individuals attending field tours were surveyed, so that we could establish direct links between growers' attitudes and behaviors and the Ralston Project. Lastly, field tour attendance assured us that surveyed growers had some level of direct exposure to the project and contact with cooperating professionals, in order to provide more detailed and meaningful data about their attitudes and behaviors.

We administered the survey using a five-part mailing system[21,22]. All mailings, except the fifth, were delivered first-class through the public postal service[21,22] (United States Postal Service). Use of a private courier service was deemed inappropriate for this study because of the distance between each respondent from the survey office and frequency of post office boxes (PO Box) listed for contact addresses. Given that private couriers only deliver to residential addresses, the removal of these individuals would have effectively lowered the population.

The first mailing was sent on 21 May 2002 in a hand-printed envelope[22]. The single-page letter described the

purpose of the survey, the importance of individuals' participation, and notice of the coming questionnaire. A packet containing a four-page, double-sided, booklet-style questionnaire and stamped return envelope[22] was mailed on 23 May 2002. Subsequent mailings were sent 3 June 2002 and 24 June 2002, but only to those individuals not responding to previous mailings. Intervals between mailings deviated slightly from the recommended protocol[21,23] to reduce costs associated with a national postage rate increase and to accommodate for growers' restrictive fieldwork schedules. A final packet containing an 8-page, single-sided, packet-style questionnaire[22] was mailed on 12 September. We selected the two-day, expedited mail service, in order to make this mailing distinctly different from previous attempts and to emphasize the importance of their participation[22]. The resulting response rate for the survey totaled 55% with a completion rate of 62%, which included individuals who answered the questionnaire but were later determined ineligible. Both rates are considered high by today's mail survey standards, especially for a survey administered during the growing season.

The questionnaire consisted of 31 open-ended, partially open-ended, closed-ended and categorical questions. We chose to include incomplete questionnaires for data analysis despite missing data, given the small population size. Eligible questionnaires were coded and frequencies tabulated using SAS® software[24]. Open-ended portions were recorded verbatim and then combined with frequency distributions for basic descriptive statistics. Next, we conducted the chi-square test of independence, $\chi^2 = (N-1)s^2/\sigma^2$ with $\alpha = 0.05$, to determine which variables had the greatest influence on the growers' decision to experiment with project technologies. Statistical tests are usually reserved for instances in which one is attempting to generalize from a sample to a population from which that sample is drawn. We attempted to survey the entire field tour population, so the more appropriate interpretation of the chi-square test used here is whether the distributions differed from a distribution due entirely to chance[25].

The demographic variables tested were similar to those tested in other local surveys[26,27] and discussed extensively within the diffusion of innovation literature[5]. The variables we tested were age, farm size, land ownership, education, previous adoption, rainfall and relative distance. We selected these specific variables based on their relevance to influencing innovativeness among individuals and predicting adoption behavior according to the diffusion–adoption model[5]. In addition, it allowed us to see how our particular population fit within the larger local grower community depicted in other surveys previously conducted within this area. The independent variables were broken down into categories shown in Table 1, and subjected to conditions given in parentheses.

All variables were obtained directly from the demographic questions in the questionnaire, with the exception of rainfall and relative distance. These were estimated using precipitation[28] and state road maps, respectively. Relative distance was determined to be the number of kilometers from the town a grower listed as closest to their primary residence (i.e., homestead) to the Ralston Project site. Rainfall was divided into three categories according to whether a grower's homestead area received less (<254 mm), similar (254–356 mm) or more (>356 mm) rainfall than recorded for the project site. Although it's not unusual in this region for growers to farm segmented fields over an extended area that may experience variations in rainfall, we could not account for such variations with this dataset.

Table 1. Categories into which the demographic variables were divided.

Age (population average)	⩽51 years
	>51 years
Education (completed degree)	High school
	Post-secondary education
Farm size (rent + owned)	Small ⩽1242 hectares
	Medium/large >1242 hectares
Land ownership (% hectares currently in production as rented)	<50% rented
	⩾50% rented
Previous adoption (of project technology prior to first visit)	Yes
	No
Relative distance (from primary residence to project site)	⩽80.5 km
	>80.5 km
Rainfall (average annual precipitation at homestead location)	<254 mm
	254–356 mm
	>356 mm

Results

Identification of growers

A total of 101 eligible growers from 16 counties across eastern Washington and northeastern Oregon participated in the survey. The population consisted entirely of males, and their average age was 51 years (Table 2) with 67% ($N = 99$) falling between the ages 40 and 60. The average duration of farming experience was 27.5 years. A majority of the growers acquired educational degrees past high school, with 56% ($N = 98$) completing a 4-year or graduate degree. The population's average farm size, excluding acreage enrolled in the Conservation Reserve Program (CRP), was 1247 ha (3080 acres) with <50% of the land owned. Only 25% of the population ($N = 98$) engaged in occupations in addition to farming. Personal characteristics of our population were fairly comparable to those of growers from other local surveys[26,27], but exceeded other surveys in terms of average area farmed and level of education.

The combination of these characteristics placed this population within the realm of innovators and early adopters[5]. Innovators and early adopters, as previously discussed, have been traditional target groups of research and

Table 2. The influence of personal characteristics and environmental conditions on growers' decisions to try out technology developed or featured in the Ralston Project.[1]

Was there anything of interest that you tried out in your own production operation?

	N	Yes	No
Age			
⩽51 years	57	60%	40%
>51 years	38	63%	37%
			$\chi^2 = 0.118$, *P* value = 0.731
Education			
High school	20	40%	60%
Vocational/2-year/4-year/graduate degree	74	66%	34%
			$\chi^2 = 4.534$, *P* value = 0.033*
Farm size			
Small farm	35	54%	46%
Medium/large farm	54	67%	33%
			$\chi^2 = 1.379$, *P* value = 0.240
Land ownership			
<50% rent	42	60%	40%
⩾50% rent	47	64%	36%
			$\chi^2 = 0.174$, *P* value = 0.676
Previous adoption			
No adoptions	39	49%	51%
1+adoptions	55	69%	31%
			$\chi^2 = 3.968$, *P* value = 0.046*
Relative distance			
⩽50 miles	36	58%	42%
>50 miles	60	63%	37%
			$\chi^2 = 0.238$, *P* value = 0.626
Annual rainfall			
Below site average	19	37%	63%
Same as site average	51	69%	31%
Above site average	26	65%	35%
			$\chi^2 = 6.136$, *P* value = 0.047*

[1] Percentages are compared between 'yes' and 'no' for test categories of each independent variable. *P* values pertain to values across the categories of variable. An * following *P* values denotes significance, with $\alpha = 0.05$.

extension. It was not surprising that other user groups were largely absent from field tours, given the long standing tradition of the winter wheat–fallow system, the complexity of the crop systems tested, the historical diffusion of no-till technology[7,10], and the tendency of field tours to attract early users of technology[11]. The size and selectivity of this population indicated that the conservation cropping systems remain in the very early stages of diffusion within the larger grower community. The presence of early adopters, who tend to have larger social networks and community influence[5], further suggests that information and technology will continue to influence attitudes and behaviors beyond the participants in field tours[11].

Diffusion of innovations

Ninety-three percent ($N = 81$) of respondents had heard of the Ralston Project by the second field tour in 1998. Fifty-four percent ($N = 98$) acquired information through university/agency researchers or cooperative extension personnel, and 32% ($N = 98$) from other growers. Additional information about the project ($N = 97$) was also obtained through industry news (78%), other field tours (66%) and grower meetings (53%). The diffusion of information about the Ralston Project thus occurred over several levels of communication and authority. This flow of information highlights an important triangulation among the grower, researcher and other growers[11] in the diffusion of agricultural innovations.

During field tours, researchers discussed their findings with respect to nine specific issues the project was set up to address (Table 3). The issues that received the highest amount of interest included: (1) economic analysis for each crop system; (2) use of no-till drills for spring planting and fertilizing operations; (3) production of continuous spring crops as an alternative to fallow; and (4) managing crop

Table 3. Survey question asked to determine growers' level of interest in the Ralston Project's experimental objectives.

Listed below are some of the issues that the research at the Ralston Project has attempted to address. Indicate whether what you observed during the June Field Day(s) or at any other time was *very interesting, somewhat interesting, not interesting, don't remember.*

	% of respondents[1]			
	Very interesting	Somewhat interesting	Not interesting	Don't remember
A. The use of no-till drill for spring planting operations and fertilizing	73	26	1	0
B. The use of crop stubble for erosion control	50	47	2	1
C. The use of crop stubble to increase soil moisture	71	28	1	0
D. The management of crop stubble to control pests/disease	44	45	6	5
E. The selection of crop varieties for disease resistance	54	42	3	1
F. The use of a spring crop rotation as an alternative to fallowing	72	22	6	0
G. The use of a spring crop cycle to increase control of pests	45	38	12	5
H. The use of spring crop cycle to increase control of plant disease	54	38	5	3
I. The economic market analysis for each crop rotation (treatment)	74	24	1	1

[1] Percentage of respondents calculated from a sample size (N) of 99, except for question A, where $N = 100$, and question C, where $N = 98$.

stubble to increase soil moisture. While 77% ($N = 94$) of the growers found one or more of these topics particularly useful (Table 3), 15% stated that everything was useful to them.

Growers did not appear intimidated by the technology of the Ralston Project. When asked if they had tried anything of interest from the project within their own farm operation (Fig. 1), 61% ($N = 96$) responded yes, with >30% trying multiple technologies. Fifty-one percent ($N = 63$) of growers reported that they permanently adopted some technology from these independent trials. In addition, 58% ($N = 3$) said they were using one or more technologies in the project prior to their first visit to the site. We suspected that the total number of new adoptions was slightly higher than recorded, after considering some individuals' hesitation to classify their changes as permanent. As one grower explained, 'My direct seeding system is constantly changing. It is hard to pinpoint ''permanent'' changes.' Finally, 41% ($N = 98$) of growers recalled sharing specific information or insights with other growers regardless of whether they adopted some technology or not.

Conservation cropping systems, such as those tested in the Ralston Project, remain difficult innovations to diffuse because of their high degree of complexity and risk[5]. These systems require more mechanical precision and abstract thinking and a higher risk tolerance over more conventional systems, as well as changes in personal beliefs, to make them work effectively[5,10]. It was not surprising to learn that almost half of the population was either unable or unwilling to adopt some of the technology. However, these growers' concerns centered more often on contextual variables, such as recent drought and market conditions, than on the direct mechanical or technical challenges to implementing the new systems. These findings suggest that the Ralston Project attracted innovative individuals who had already adopted project technology, as well as individuals, users and non-users, interested enough to adopt once conditions became more consistent.

The combined rate of use and adoption was high among this population, especially given the complexity of the treatment systems tested over a rather short period of 5 years. Some might argue that individual technologies used (e.g., no-till drill) have been around longer than the 5 years of the project. However, since older technologies were used within a newly developed crop system, the technologies collectively constituted new invention. In other words, a new innovation subjected to a new diffusion timeline. Regardless of this point, the high level of interest (Table 3), combined with the documented use and adoption rates, show that collaborators' efforts to improve technology transfer through field tours were successful. The recorded levels of interest, use and adoption also provided a positive outlook for further diffusion. The current state of diffusion into the larger grower community (i.e., technology transfer has begun to influence the masses) would best be confirmed with a follow-up survey of growers following the final field tour, held 1 June 2004. The continued diffusion of the Ralston Project's cropping systems and associated technology may require researchers to rethink their current technology transfer activities, to better fit the concerns and priorities of the latest user group(s) to show interest in the project.

Growers' attitudes and behaviors

The final section of the survey questionnaire asked growers how project collaborations, funding sources and design characteristics affected their overall opinion of the Ralston Project (Table 4). The project's collaborations did not have as great an impact on growers' opinion as did project

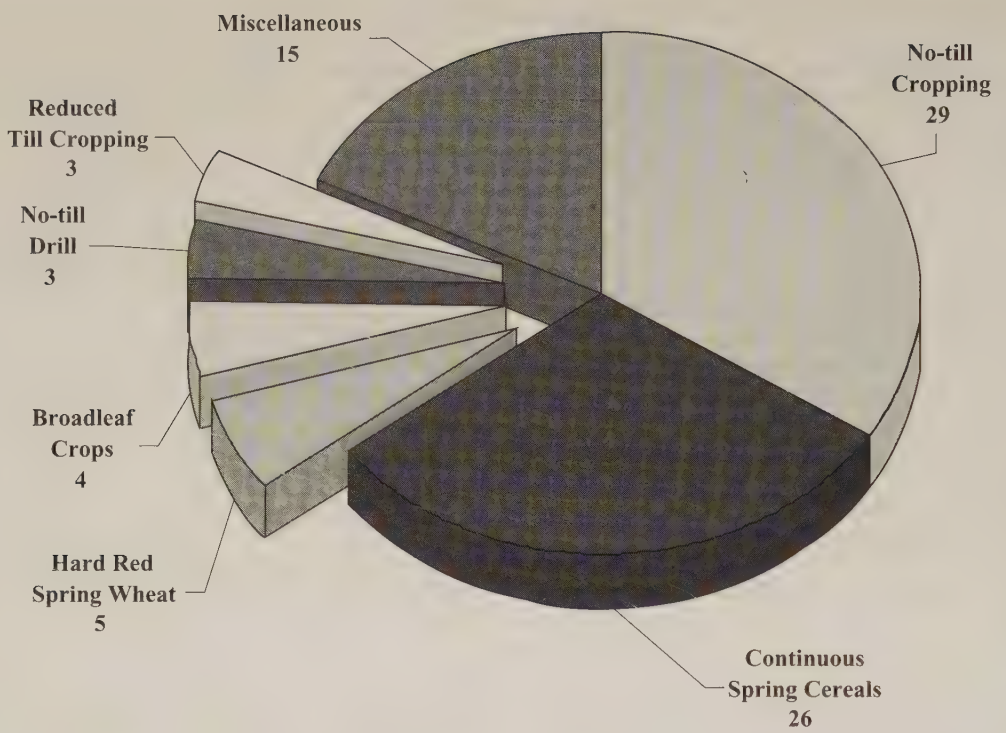

Figure 1. The number of independent trials by growers with individual technologies used in the Ralston Project, based on the survey question, 'Was there anything of interest from the Ralston Project that you have tried out in *your* farm operation?' 'No-till cropping' also represents direct seeding and recropping; 'Continuous spring cereals' represents unspecified spring wheat and other spring cereal rotations; 'Hard red spring wheat' also represents dark northern spring wheat varieties.

Table 4. Survey question asked to determine how research funding sources and experimental design influenced growers' opinions of the Ralston Project.

	% of respondents		
	Improved opinion	**Worsened opinion**	**No change[1]**
Funding[2]			
A. The Washington Wheat Commission co-funded the Ralston Project	48	3	49
B. STEEP III and CP_3 co-funded the Ralston Project	48	7	45
C. WSU and OSU co-funded the Ralston Project	58	1	41
D. The USDA-ARS co-funded the Ralston Project	50	2	48
E. Public and private organizations cooperatively funded the Ralston Project	47	0	53
Design[3]			
A. Local growers' input was used to determine the crop rotations of the experiment	81	1	18
B. Local growers and researchers cooperatively designed the Ralston Project	79	2	19
C. The Ralston Project was conducted on a private grower's land	57	0	43
D. The USDA-ARS directed the Ralston Project	31	7	62
E. The Ralston Project was designed as a long-term experiment (×2 crop rotation cycles)	82	0	18
F. The Ralston Project was designed to use farm-size equipment	90	0	10
G. The Ralston Project was designed to look at elements that affect crop production simultaneously (e.g., soil, weeds, disease, economics)	91	0	9
H. The Ralston Project involved researchers from several different universities	78	1	21

[1] 'No change' was regarded as a positive response, although it did not provide a clear indication of how good or bad current opinion was.
[2] Percentage calculated from a population of 96 respondents, except question E where $N = 97$.
[3] Percentage calculated from a population of 100 respondents, except questions C, F, H, where $N = 99$, and question D, where $N = 97$.

planning and design. Most collaborations either improved or had little effect on growers' opinion, although the involvement of academic institutions improved the opinion of 58% ($N = 96$) of growers. This was the highest improvement rating among all causative factors. This result likely stems from a long-standing relationship between agricultural producers and the local land grant universities. Project funding through federal conservation research programs (STEEP and CP_3) left 7% of growers with a lower opinion of the project, and may be attributed to a belief that increased environmental regulations prompted funding. As one grower speculated, 'There seems to be a big government push to make direct seed mandatory for all ag [agriculture].'

The design and planning of the Ralston Project substantially improved growers' opinions of the project. The elements of significant influence (Table 4) included the project's integrated and multiple component research (91%), plot size (90%), project duration (82%), grower input (81%) and growers' collaboration with researchers (79%) from several universities (78%). Many growers felt that the project's credibility resulted from researchers' designation of entire cropping systems as individual treatments; plot design that accommodated commercial-size equipment, and use of a grower advisory panel. In contrast, a small number of individuals felt that the project's credibility was weakened because investigators selected a site that they considered unrepresentative of regional topography, and by the poor economic performance of the new crop rotations. Still, several growers clarified that the value of the Ralston Project to them increased because, 'one technique was not stressed for success...environmental factors and economic sustainability were [collectively] addressed to benefit growers in these challenging farming areas'.

According to the diffusion-adoption model, individuals are often motivated to seek evaluation information about an innovation in order to learn about potential consequences of use and to reduce uncertainty[11]. Much of the Ralston Project's underlying appeal came from its ability to absorb some of the risk, normally borne by the growers, in learning, implementing and adapting the technology in conservation cropping systems to drier areas of the inland Northwest. In other words, positive changes in growers' opinions manifested a confidence in the research that, in turn, reduced the perceived risk of use of new crop systems or farming practices and encouraged use and adoption. Two growers explained that, 'It helps that I don't have to try to fail or succeed because they are closely monitoring and experimenting in so many areas [affecting production]', and 'Any help to try new things without sacrificing potential income is crucial [to me]'. Such positive changes in attitude are important indicators of future behaviors toward adoption[5]. However, it is harder to speculate about the project's impact in other areas, or among other growers in our region, because field tour participants differed from other growers randomly sampled in other regional surveys[26,27].

What evidence is there that the Ralston Project will ever impact growers beyond those at field tours? Again, the presence of peer-influencing individuals[6] within this population, a majority of positive attitudes toward the project, and the documented movement toward use and adoption increases our confidence in the extension of the project's impact beyond field tours. In addition, the continual participation of growers in project planning and evaluation appears to have had an effect on their communication with other growers. This means that as the number of individuals using part or all of the newly developed crop systems increases, and they share their experiences, the more risk and uncertainty decreases for hesitant growers, helping them move further through the decision-making process.

Deciding to experiment with new technology

The disciplinary study of innovation diffusion has defined sets of character, contextual and environmental variables that help predict the likelihood of an individual's adoption of new technology[5]. Of the seven variables tested (Table 2), growers' level of formal education, their previous adoption of technologies used in the Ralston Project, and the average annual rainfall received in their homestead area significantly influenced their decision to try out (other) project technologies. Education was a significant factor ($P < 0.05$) once we pooled all forms of post-secondary education into one test category. Sixty-six percent ($N = 74$) of growers having post-secondary education experimented with project technologies, compared to only 40% ($N = 20$) of growers with only a high school education. We also found that growers who adopted technology used in the project prior to their first visit to the Ralston Project, tried out other technologies 20% more often than those with no adoption history. Not surprisingly, these independent trials occurred most often among growers located in areas receiving similar average annual rainfall (254–356 mm) to the project site. Discrepancies in experimentation rates among growers of different rainfall regimes is easily explained by the biological limitations of spring cereal varieties in areas receiving <254 mm of rain, in addition to multiple years of regional drought in the late 1990s.

Again, we tested these seven variables over the population of growers who attended Ralston Project field tours. It would not be prudent to make assumptions about how significant these variables would be within the larger grower community, nor if they would serve as the best predictors of adoption for the community as a whole. This is especially true after having already established our population as primarily innovators and early adopters, a fairly small proportion of any given community in terms of innovation diffusion[5]. What we gained from testing these variables was the greater sense of the factors currently motivating the use and adoption of conservation cropping systems within our area and, more specifically, who was impacted the most from field tours. Ralston Project field tour events catered toward both non-adopters and adopters,

but had a bigger influence on those individuals with a prior history of using the technologies incorporated within the project. This case study showed that among more innovative groups of commercial growers, personal characteristics significantly reduced the limitations of environment, which is generally perceived by growers as a major hindrance to use and adoption of conservation-based farming technology (personal communication).

Conclusion

The development of profitable conservation cropping systems for commercial-scale production remains difficult and slow because of the tension between short-term economic stability[29] and long-term biological sustainability[30]. In addition, the complexity of such systems does not encourage immediate or even complete adoption by end users[5,7], compounding a researcher's difficulty in justifying their costs and contributions to science and industry. Public field tours, a long-standing tradition of Extension, provide an excellent means of disseminating information, directly exposing interested growers to innovative research, and provide opportunities for idea exchange between the developers and users of technology. The evaluation of the Ralston Project revealed that collaborating researchers' unconventional planning and design strategies increased the effectiveness of its field tours in transferring technology. The combined efforts of researchers and growers to design and evaluate a long-term, large-scale, multidisciplinary field study improved the researchers' ability to: (1) mimic common field conditions; (2) study whole crop systems over several rotations; and (3) improve the applicability of developed techniques to growers' own operations. These strategies resulted in high use and adoption rates among the growers, and positive changes in attitudes toward the project as a whole among adopters and non-adopters alike.

In the midst of decreased time horizons, global competition, and the increased costs of field research, conservation-based field researchers should continually explore ways to maximize the potential of their technology transfer activities. Researchers can accomplish this successfully by understanding more about the characteristics of their target audience in relation to the greater farming community, and how the characteristics of their research technology affect its transfer. By understanding these relations, researchers may discover new ways to increase the receptiveness of their audience and influence attitudes and behaviors that foster adoption. As conservation-based farming technology continues to evolve, the ways in which researchers plan and design experiments becomes as important to adoption and diffusion as developing the technology itself.

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Common support for local agriculture in two contrasting Oregon communities

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Abstract

One increasingly successful approach to enhancing small farm viability is for farmers to market their products directly to consumers and food-oriented businesses and institutions within their local area. This localized approach to food production and distribution is based on theoretical concepts often articulated as community, local or regional food systems. But is there sufficient consumer support to make local food systems viable? Do communities differ in their potential for developing a local food system based on their dominant socio-economic and/or political characteristics? This study reports on the results of a random mail survey of households in two Oregon communities. Although the two communities contrast socio-economically and politically, they show common but somewhat different support for local agriculture. The results demonstrate the potential for the development of more localized food systems in both communities. However, the type of products, their method of delivery and pricing will likely need to be tailored to fit each community.

Key words: local food systems, farm direct marketing, consumer preferences

Introduction

While the mainstream of the food and agriculture system continues to move toward the increasing 'commodization' of products within a fiercely competitive global marketplace, some producers and some consumers are developing new, attractive possibilities on the fringes of that system. The study presented here explores the potential for expanding profitable local market opportunities for small farmers through an assessment of the support for local agriculture in two communities with very different socio-economic and political characteristics, and by identifying a segment of the general population that is interested in purchasing local farm products.

It is well documented that the process of consolidation in US agriculture has reduced market opportunities for small farms[1,2]. Innovative producers have developed niche markets that are profitable. While substantial research indicates that most US consumers want their food to come from sources within their region[3], to date, only a minority are devoting the time and money needed to seek out the high quality and unique agricultural products and services that can foster profitable small farms.

A needs assessment of small farmers in one region of Oregon conducted during the late 1990s indicated that there was a diminishing number of market outlets available to these farmers, and that the prices offered through the remaining markets were generally too low for their farms to be profitable[4]. These farmers maintained that although there were crop production issues that needed attention, their most pressing concerns were related to marketing. At about this time, the National Commission on Small Farms concluded that small farms were being forced out of business not by market forces but by the loss of market opportunities resulting from agribusiness consolidation and federal government policies that favored large farms[2].

One increasingly successful approach to enhancing small farm viability is for farmers to avoid wholesale markets completely by marketing farm products directly to consumers and food-oriented businesses within their local area. A local food economy, as Feenstra[5] points out, creates profitable market niches for small farmers. This localized approach to food production and distribution is based on theoretical concepts, often articulated as 'community, local, or regional food systems' (hereafter referred to as local food systems). Local food systems are defined as 'a collaborative effort to build more locally based, self-reliant food economies—one in which sustainable food production, processing, distribution, and consumption is integrated to enhance the economic, environmental, and social health

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of a particular place'[6]. Some authors have applied the concept of 'bio-region' to food systems and utilize the term 'foodshed' to represent the region that supplies, or can potentially supply, a significant quantity of a community's food needs[7]. The 'ecological footprint' is another model incorporating similar concepts into a calculation of the land area necessary for communities to self-reliantly produce food and fiber, and to cycle wastes[8].

While sustainable agriculture proponents broadly support these theoretical approaches, a number of practical questions remain to be answered. Is there sufficient consumer support to make local food systems viable? What are the barriers and opportunities for consumer purchases of locally produced food? The concept of a local food system generally utilizes single or multiple municipalities as its economic base for the sale of farm products within a region. Does this approach work in all communities? Do communities differ in their potential for developing a local food system based on their dominant socio-economic and/or political characteristics?

Background

A number of studies have been conducted during the past two decades focusing on consumer interest in locally produced food. Some studies have identified low or indifferent interest[9,10], but most have reported a general interest in locally produced food[11–13]. A recent national survey of registered voters revealed: 81% want their food to come from within the USA and 52% want their food to come from their own state. In addition, 54% said they have purchased from a farmers' market and 40% reported buying from a farm stand during the previous year. The researchers concluded that these figures 'reflect a strong undercurrent in the American marketplace'[3].

Several studies have identified demographic information related to consumers who purchase local products[11,14–16]. However, these studies have focused on consumers at specific market outlets, such as farmers' markets or roadside stands, and not on consumers from the general population.

Comparisons of communities concerning consumer acceptance of regional and local food systems are not well developed in the literature. Lockeretz[17] examined six communities considered to be 'working class to affluent' in eastern Massachusetts. Although, in general, he found support for local agriculture, his examination did not specify similarities or differences among the communities. In an Indiana study, Jekanowski and associates[12] included 'rural, small town and urban communities' in their study and found that the type of 'community' had no effect on the likelihood of purchasing local products. These examinations do not specify similarities or differences between communities in their interest in local agriculture. With the exception of the study by Eastwood and associates[10] of consumers in Knoxville, Tennessee, research using the community as the unit of analysis related to consumer preference for local products is rare.

This study fills important gaps in the research related to consumer interest in locally produced food. It examines preference for local food based on age, income and education; documents consumer behaviors and product preferences; and compares consumers in two communities with different socio-economic and political characteristics. The questions asked and the variables analyzed were selected for an additional purpose beyond this academic goal: they also directly contributed to the informational needs of local producers.

Methods

This study was precipitated in part by the previously noted needs assessment of small farmers in one region of Oregon[4]. To maintain farmer involvement in this research, a nominal participatory approach was utilized. An advisory group of 10 farmers and local food advocates was assembled to provide guidance and input to the research process and to assist in formulating a questionnaire to be administered to consumers. The farmers produced a variety of products (vegetables, cheese, processed foods, meat) and were already engaged in marketing their products locally.

The process employed with the advisory group consisted of an initial brainstorming session, to identify questions for the consumer questionnaire, and a follow-up session several weeks later, to review a draft of the consumer questionnaire. After the survey was completed and the data analyzed, a workshop was conducted to present the findings to interested farmers. Some members of the advisory group acted as panelists interpreting the data during this workshop. The entire study was organized and conducted between September 1997 and June 1998. Although this project was not a fully participatory research project, it represents what van de Fliert and Braun[18] regard as 'platform building', or partnerships between farmers and researchers that produce tangible, useful results on a topic generated by farmers.

The brainstorming session was facilitated to elicit from the advisory group their responses to the question: 'What do you want to know from consumers that could improve your business?' Farmers were primarily interested in the extent of consumer interest in local food products and what prices they would pay. Based on input from the advisory group, a review of the literature, and the research interests of the authors, a questionnaire utilizing both open-ended and closed-ended questions was constructed. This survey was just a first step in a longer-term effort to address producer research priorities. The questionnaire probed for respondent attitudes and behavior toward local products and demographic information. Respondents provided the following categories of information:

- shopping patterns;
- desired product characteristics;
- quality perceptions of local versus non-local food products;
- history of buying local food products;

- perceptions about relative safety, quality and price of food products;
- barriers to buying local farm products;
- attitudes toward and reasons for supporting local agriculture;
- age, income and education.

For the purposes of the survey, the term *local* was defined to be food products grown and/or processed within a 50-mile radius.

The survey was mailed to consumers in a random sample of 500 households in Albany and Corvallis, Oregon during the winter of 1997–98. The sample included 250 households in each community, based on postal zip codes. The survey sample was drawn by Survey Sampling, Inc. of Fairfield, Connecticut. The survey was conducted using the total design method[19,20]. A total of 315 usable surveys were returned—half from each community—for a response rate of 63%. This high response rate allows confidence in extrapolating the results to the population of the two communities as a whole. The Survey Research Center at Oregon State University was consulted throughout this study regarding sample selection, final development of the survey instrument and data analysis. Chi-square tests were utilized to identify statistically significant differences.

The Communities

For ease of communication, we are defining a community as 'a group of people living in the same locality and sharing some characteristics', as per the International Fund for Agricultural Development[21]. We acknowledge that 'individuals usually belong to many different communities that are contextually activated and provide different identities'[22] and note that the two communities in our study are made up of many communities.

Albany and Corvallis are communities located 10 miles apart in Oregon's Willamette Valley about 80 miles south of Portland. They have similar sized populations: Albany with approximately 40,000 residents and Corvallis with approximately 50,000. They both sit in the midst of thriving agricultural production areas, with most of the products being shipped out of state or out of the country. The dominant agricultural land uses are extremely large grass seed farms, Christmas tree plantations and private woodlands. Smaller, but still significant, acreages are in processed vegetables, mint and cereals. Even smaller in terms of acreage are the many small and/or part-time farms that produce a wide variety of agricultural products, with a focus on fresh fruits and vegetables, bedding plants and flowers.

There are clear differences between the two communities, related to the occupations and educational levels of residents. Albany relies to a large degree on a diverse manufacturing industry, including exotic metals and wood products, while Corvallis is home to a major university and high-technology industry. Albany, therefore, has a higher percentage of jobs in the manufacturing sector and Corvallis has higher percentage of jobs in the high-technology and education sectors (Table 1). There are further differences in educational attainment as well. Residents of Albany who have a Bachelor's degree or higher represent about 18% of the population, contrasting with 53% of Corvallis residents. The percentage of individuals who did not finish high school is 15% for Albany and 7% for Corvallis (Table 1).

Table 1. Occupation and educational attainment of Albany and Corvallis residents[23].

	Albany (%)	Corvallis (%)
Industry		
Education, health, social services	21	35
Professional and scientific	6	11
Manufacturing	21	14
Education attainment		
Did not finish high school	15	7
Bachelor's degree or higher	18	53
Graduate or professional degrees	6	25

The two communities also differ in income levels and age of residents. The median family income for Albany is $US46,094, versus $US53,208 for Corvallis. Median age for Albany is 34.6 years, as compared to 27.0 years for Corvallis[23].

Based on voting behavior, Albany tends to be more conservative politically while Corvallis is more liberal. The elected member to the Oregon House of Representatives for the district dominated by Albany is a Republican. The representative for the district dominated by Corvallis is a Democrat[24]. Although both communities excel in providing a wide array of recreational and cultural events, the traditional character of each community may be best represented by their single largest community events. Corvallis hosts Da Vinci Days, a summertime celebration of Leonardo da Vinci, featuring art, music, science, and technology; while Albany hosts the World Championship Timber Carnival, the world's largest outdoor timber sports competition. These popular events are indicative of Corvallis' cerebral and highbrow tendencies that contrast with Albany's appreciation of the physical skills of a locally esteemed occupation.

Results

Combined sample results

The combined sample results reveal where, how and why consumers in both communities access local agricultural products. Consumers indicated they purchase local agricultural products for a variety of social, economic and food quality reasons (Table 2). Social and economic reasons include a desire to keep farmers in the area, to support the local economy, and enjoyment of the experience of shopping for local farm products. Food quality reasons

Table 2. Why consumers buy local farm products.

Reason	Very important (%)	Somewhat important (%)
Keep farmers in the area	46	41
Support local economy	44	45
'Local' products are better	44	44
Confidence in 'local' products	42	45
Enjoy buying experience	30	42

Table 3. Type of outlet and frequency of shopping.

Outlet	10+ times per year (%)	1–9 times per year (%)
Supermarket	94	5
Farmers' market	13	46
Roadside stand	7	46
U-pick	3	36

include the belief that local products are better, and greater confidence in quality and safety of local products.

Tables 3 and 4 show the types of food outlets utilized and the frequency of shopping by respondents. Table 3 indicates that between approximately one-third and one-half of the population shopped at least once at each of the types of outlets that feature local products (farmers' markets, roadside stands and U-pick farms). Consequently, there is a high level of familiarity with these outlets. However, Table 3 also reveals that supermarkets are the only food distribution channels that are frequented on a routine basis by anything but a small minority of respondents, and Table 4 shows that 69% of the population shops only once a week or less. Further, when asked what barriers they perceived to buying local agricultural products, consumers indicated the primary reasons were that these products were not available where they shopped, and they were not available when they shopped (Table 5). This is a major barrier that would have to be overcome in order to greatly increase sales of local agricultural products.

An additional barrier for a small percentage of respondents was what they perceived as the high price for local agricultural products (Table 5). In their written comments from open-ended segments of the questionnaire, this latter group indicated they thought local farm products should be less expensive because transportation costs are lower.

Most consumers were willing to pay a premium for local agricultural products. When asked, 'given two similar products, one grown locally the other grown elsewhere, and given the product grown elsewhere cost $1.00, what would you be willing to pay for the local product?' by far the largest portion of the sample, 50%, responded that they would pay more for the local product. Only 16% said they would pay less for the local product (Table 6).

Table 4. Frequency of shopping at outlets featuring local products.

Frequency of shopping	Percent of sample
Every 2 weeks	11
Weekly	58
Several times per week	31

Table 5. Barriers to buying local.

Barrier	Greatly (%)	Somewhat (%)
Not where I shop	38	47
Not when I want it	35	53
Price too high	31	39

Additional analysis

In addition to analyzing the entire data set, Chi-square analyses were performed on data related to these variables: income, education, age and community, and an index variable for 'local' support. The 'local' variable is a composite variable based on responses to 17 questions. Eight of the 17 questions are behavioral. Three of the behavioral questions address whether the respondents had shopped in the previous year at marketing outlets that are dedicated to local products (farmers' markets, roadside stands and U-pick). The other five behavioral questions determine which broad categories of local food products (fruits, vegetables, protein products, wine and processed products) respondents had purchased in the previous year.

Nine of the 17 questions focused on attitudes toward local food products. Five of the attitudinal questions probed whether the respondent considered specific factors in deciding whether to buy local products:

- supporting the local economy;
- keeping farmers in local area;
- belief that local products are better;
- greater confidence in local products; and
- enjoyment of the local buying experience.

Three additional attitudinal questions examined whether the respondent valued knowing the producer, selected local products when given the choice, and believed that local products were generally of superior quality. The final attitudinal question asked respondents to quantify their willingness to pay a premium for a local product as compared to a similar non-local product.

Consumers formed an approximately normal distribution, ranging from those strongly supporting local farm products to those who were negative toward local farm products. The distribution was split into four segments based on breaks in frequencies. Table 7 shows the categories of the sample based on level of support for local farm products derived from the 'local' index variable.

Table 6. Price consumers are willing to pay for local food products.

	Percent of consumers willing to pay:							
	Less			Same			More	
Price ($US)	**0.50**	**0.67**	**0.75**	**1.00**	**1.10**	**1.25**	**1.33**	**1.50**
%	6	1	9	35	24	18	3	6
Sum		16					50	

Table 7. Categories of support for 'local' farm products from 'local' index variable.

Level of support for 'local' farm products	% of sample
Strong support	18
Moderate support	26
Indifferent	31
Negative	26

The 'local' index variable provides a means of focusing on the sharp contrast between different consumer segments in this region (Table 8). Since all these are variables included in the calculation of the index, it is not appropriate to make statistical comparisons.

Income, education, age and support for 'local'

Income level and education level were not associated with support for local agricultural products. Comparing these two important socio-economic indicators to the index variable for local did not show a strong association. However, age was strongly associated with support for local food products (Table 9). Age categories for survey respondents were grouped based on the breaks occurring in the sample's frequency distribution. The age groups were: 21–29, 30–45, 46–64 and 65–86 years.

In order to simplify the analysis, in Table 9 the two middle age categories (30–45 and 46–64) are grouped together. The table then shows how the younger and older consumers differed from those in the middle age group. In the interest of brevity, the data from this table are not repeated in the text, but the basic differences are highlighted in the paragraphs that follow. Seventeen variables had significant differences related to age. Table 9 shows six of the most interesting.

In many ways the youngest consumers were the least supportive of local agricultural products. They had very different food buying habits and attitudes, shopping less frequently than other age groups and expressing less concern with food appearance, freshness, safety, and environmental friendliness (Table 9). They were least likely to buy local agricultural products and perceived these products to have limited availability. Although not statistically significant at the 0.05 level, they were also less supportive of the local economy and local farmers than other age groups.

Table 8. Comparison of strong and negative categories.

	Strong (%)	Negative (%)
Value knowing producer	33	4
Frequent farmers' market patron	24	0
Feel 'local' produce is superior	93	23
Buy 'local' to support economy	79	8
Enjoy 'buying experience'	58	0
Willing to pay 33% or more extra	31	2

The middle age groups (30 to 45 and 46 to 64 years old) were the most supportive of local agricultural products. They were more likely to support these products for reasons of quality, social consciousness and the enjoyable experience associated with shopping for and buying fresh food.

Comparison of the two communities

Comparison of the communities of Albany and Corvallis revealed that although they clearly differ in terms of affluence, education and other social and political traits, there were only a few differences between the two communities in their support for local agricultural products. The communities were compared for more than 50 different variables (summarized in the Methods section). There were statistically significant differences in only 11 (Table 10). Most strikingly, the index variable for 'local' did not differ between the two communities, indicating a common and fairly high level of support for local farm products in both communities.

For the two communities, there were no differences in reasons for preferring local products, attitudes toward the environment and organic food, perceived barriers to buying local products or the perception of relative quality of 'local' products. In addition, there were few differences in the factors respondents considered in buying products, buying habits both in terms of outlets and types of products, and in perceptions of local product availability.

Table 10 highlights the areas of food attitude and consumption differences between Albany and Corvallis. An additional 7% (95% versus 88%) of Albany consumers expressed a preference for US as compared to imported food products. This could be linked to greater interest in imported gourmet food products by Corvallis residents. More Albany consumers patronized a roadside stand in 1997 (66% versus 46%). Also, 81% of Albany consumers had purchased local dairy and/or meat products in the past year, compared to 67% of the Corvallis consumers. Albany consumers were more discriminating in selecting food products. A higher percentage of Albany consumers placed an emphasis on food appearance (64% versus 46%). They

Table 9. Significant age-related differences in food buying habits and priorities.

	Age groups			
	20–29	30–64	65–86	Chi-square*
	%			
Shopping frequency (several times/week)	8	37	30	0.013
Appearance of food	33	55	66	0.017
Freshness of food	83	92	98	0.034
Safety of food	43	71	75	0.012
Environmental friendliness of food	11	31	39	0.025
Bought 'local' food in 1997	64	88	85	0.005

* Significant at $P \leq 0.05$.

Table 10. Food sourcing patterns: contrasts between Albany and Corvallis residents.

	Albany (%)	Corvallis (%)	Chi-square*
Prefer US to imported products	95	88	0.027
Roadside stand patron	66	46	0.003
Aware 'local' dairy/meat are available	81	67	0.031
Food cooperative patron	22	39	0.001
Believe 'local' more expensive	15	32	0.001
Willing to pay at least 10% more for local	43	57	0.047
Appearance of food products	64	46	0.013
Concerned about quality of 'local'	65	42	0.001
Concerned about safety of 'local'	62	43	0.009
Concerned about packaging of 'local'	58	41	0.017
Purchased 'local' fruit	90	97	0.031

* Significant at $P \leq 0.05$.

were also more likely to state that their purchases of local food products were at least somewhat limited by quality concerns (65% versus 42% for Corvallis consumers), safety concerns (62% versus 43%), and packaging concerns (58% versus 41%).

What stands out for the Corvallis consumers is that more than twice as many (32% versus 15%) perceived local product prices to be higher, and 57% of Corvallis consumers versus 43% of Albany consumers were willing to pay 10% or more in addition for local products. A greater number of Corvallis consumers (39%) than Albany consumers (22%) had shopped at least once in a food cooperative in 1997.

We interpret these data to indicate that Albany residents may have ties with local food products via the practices of freezing and canning foods (obtaining locker meats and utilizing roadside stands). Conversely, Corvallis residents may be developing a link with local food products through other local food outlets, such as food cooperatives and community-supported agriculture farms.

Discussion and Implications

Consumers indicated that they purchase local agricultural products for a variety of social, economic and food-quality reasons. The majority (87%) said the purchase of local foods to support local farmers was very important or somewhat important. This is consistent with findings from a survey of households in four midwestern states, where 70% of the respondents said it was very or extremely important that their food purchase supported a local family farm[13]. Less support for local farmers was found by Bruhn and associates[9], where 40% of respondents in their California study purchased local food products to support local agriculture. Only 30% of Delaware residents surveyed by Gallons and associates[11] listed support for local farmers as very important.

Most Albany and Corvallis consumers are willing to pay a premium for local agricultural products. This is consistent with findings from a New Jersey study that revealed 75% of consumers were willing to pay a premium for locally grown produce[25].

Of significance, income and education levels were not associated with support for local agricultural products. Interest in local food cut across educational and income levels. This is not consistent with findings from New Jersey, where farm-direct market patrons were identified as having higher levels of education and higher incomes[14].

Age was strongly associated with support for local food products. Middle age groups (30–45 and 46–64) were the

strongest supporters. Younger (21–29) and older (65–86) groups were the least supportive of local agriculture. This is similar to findings by Govindasamy and Nayga[14], where most New Jersey farm-direct patrons were middle aged (36–50 years).

Although between one-third and one-half of the population shopped at some type of farm-direct market outlet at least once during the year, most consumers (94%) shop at supermarkets and shop once, or less, per week (69%). This presents a major challenge to marketers of local agricultural products. Buying local agricultural products generally involves an extra shopping trip, perhaps on a specific day of the week, to a specialized outlet. The expansion of the sales of these products does not represent the mere substitution of one good for another. It requires instead a change in shopping habits—a conscious decision by consumers to spend more time and probably more money on food.

In fact, consumers in this study indicated that the primary reasons they didn't buy local agricultural products were that these products were not available where they shopped or when they shopped. These findings are consistent with those of Kezis and associates[26], where inconvenience and 'none nearby' were the primary reasons consumers did not frequent farm-direct outlets. Lehman and associates[16] found that as travel distance increases, the likelihood of frequenting a farm-direct market decreases. An Indiana study revealed, 'despite the desire to purchase local products expressed in our survey, consumers appear to be unwilling to incur the search and time costs involved in purchasing some of their food directly from the farm, or from and organized farmers' market'[12]. In addition, The Hartman Group[27] demonstrated that consumers are interested in environmentally friendly food but desire products to be available conveniently.

How much support is there for local farm products? About 44% of the sample, according to the index variable for 'local' support, are strong or moderate supporters of local agriculture. As noted above, this group also cuts across education and income categories. This number is equally distributed between the study communities.

A key message for farmers is that within the 44% of consumers who support local agriculture, there are 18% of consumers who seem to be highly committed to accessing local food products. This means they are willing to forgo some convenience. However, the balance (26%) has a lower level of commitment to accessing local food. Increasing local food sales to this population may require new marketing strategies, such as increasing the level of convenience.

Although Albany and Corvallis are different socioeconomically and politically, the two communities show equal support for local agriculture. The results indicate that there is potential for the development of more localized food systems in both communities. The high percentage of consumers who support local agriculture far exceeds the percent of consumers who currently patronize available venues for purchasing local food, indicating potential for expansion of local farm-product markets. However, the type of products, their method of delivery and perhaps pricing will likely need to be tailored to fit the desires of each community.

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Risk and risk management in organic agriculture: Views of organic farmers

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Abstract

In a series of focus groups during 2001 and 2002, organic farmers from different regions of the United States identified a wide range of risks to their operations. The focus groups were facilitated by the University of Maryland in cooperation with a research team from USDA's Economic Research Service, to explore the risks faced by organic farmers, how they are managed, and needs for risk management assistance. Contamination of organic production from genetically modified organisms was seen as a major risk, particularly by grain, soybean and cotton farmers. Focus-group participants producing grains and cotton—many of whom knew about and had obtained crop insurance—raised concerns about coverage offered, including the need for insurance to reflect the higher prices received for organic crops. Most fruit and vegetable producers participating in the focus groups had little knowledge of crop insurance. When provided with basic information about crop insurance, operators of small fruit and vegetable farms were skeptical about its usefulness for their type of operation.

Key words: focus groups, organic farming, crop insurance, organic certification, genetically modified organisms

Introduction

The business of farming is inherently risky. Variation in weather, insect infestations and plant diseases, for instance, can hurt crop quality and reduce yields; small changes in aggregate supply and demand for agricultural products can lead quickly to substantial changes in prices; and changes in regulations can alter farmers' production practices and costs. In addition to production and price risks, farm businesses are also often exposed to financial risk associated with borrowing capital, and farm operators and farm workers face personal health risks associated with the farm environment and working conditions[1].

Risk is generally described as 'uncertainty that affects an individual's welfare, and is often associated with adversity and loss'[2]. Several studies have examined the relative importance of different risks and management strategies for different farms. A 1996 USDA survey of US farmers noted that concerns varied by farm enterprises and geographic regions[2]. For example, cotton and grain farmers were more concerned about risk from yield loss and price variability, while livestock and specialty crop producers were more concerned about risks from institutional changes in policies and regulations.

Organic farming, which is distinguished from conventional farming by its reliance on the natural processes of ecosystems, may present particular risks and ways of managing risks. Organic farming systems virtually exclude what are often thought of as important risk management tools in conventional farming, such as the use of synthetic chemicals and antibiotics. Instead, organic farmers rely on their understanding and management of cultural practices such as crop rotation, timing of planting and harvesting, mechanical cultivation, and development of beneficial insect populations.

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Several studies of the characteristics of organic and sustainable farms have included an examination of risk management issues. Duram[3] reported that organic farmers expose themselves to special risks during the 3-year transition period from conventional to organic. Yields may drop, and transitioning producers are not able to obtain the higher prices that come with certified organic production. Also during the transition, farmers are learning a different way of farming, potentially with a different set of crops, building up the organic matter in their soil, and identifying new sources of information and inputs. Sustainable agriculture farmers in Kansas referred to the transition period as a time of 'thinking risks'[4].

The Organic Farming Research Foundation (OFRF), a California-based nonprofit organization, has conducted four national surveys of organic producers between 1993 and 2001, to explore various issues, including production risks in the organic sector. In 1997, survey results indicated that organic farmers were facing serious shortages of some organic inputs on a national basis, and were facing shortages on a regional basis for others[5]. Preliminary results of the 2001 OFRF survey found that 30% of the respondents felt that 'the risk of contamination of their organically grown farm products from genetically modified organisms (GMOs) is high to very high', and 55% of respondents 'do not feel that a regulatory framework is in place to adequately protect their organic farm products from damages due to possible contamination by GMOs'[6]. The use of non-organic inputs could mean loss of organic certification, and contamination by GMO pollen could mean loss of markets. For example, USDA and international organic regulations prohibit the use of GMOs in organic crop production, and consumer tolerance for their accidental presence in organic crops is limited.

Concerns about personal risk from occupational pesticide exposure and environmental contamination may be especially important to organic farmers. The Environmental Protection Agency estimates that 10,000–20,000 physician-diagnosed pesticide poisonings occur each year among approximately 3,380,000 US agricultural workers[7]. The extent of chronic illness resulting from pesticide exposure is much less documented. Epidemiological studies of cancer suggest that farmers in many countries, including the United States, have higher rates than the general population for Hodgkin's disease, leukemia, multiple myeloma, non-Hodgkin's lymphoma, and cancers of the lip, stomach, prostate, skin, brain and connective tissue[8]. Emerging case reports and experimental studies suggest that pesticide exposure is a risk factor for neurodegenerative diseases and other non-cancer illnesses[9]. Many of the organic farmers profiled in alternative agricultural studies include concerns about chemical use as motivations for farming organically[10,11].

While organic farming has a long history, its recent rapid growth may have increased risks for organic farmers. Between 1997 and 2001, US farmers and ranchers added about 1 million acres of certified organic cropland and pasture, and the number of farming operations with certified organic acreage, excluding subcontractors, increased from about 5000 to nearly 7000[12]. The average size of certified organic farm operations increased as well during this period, as existing organic farmers expanded their operations and new large-scale operations became certified. Dobbs et al.[13] indicated that 'price premiums associated with organic niche markets and ''family farms'' are at risk when large-scale organic producers or processors enter the market, if demand does not expand sufficiently'.

On the other hand, organic production techniques, particularly crop rotation, can reduce risk in the longer term. Hanson et al.[14] compared a conventional grain rotation with an organic grain rotation during the first 9 years of production. Without organic price premiums, the average annual profits of the conventional rotation were higher than the organic rotation. However, using a safety-first criterion, the risk-averse farmer would choose the organic system over conventional. More specifically, Diebel et al.[15] noted that with diverse cropping systems, the yields and prices of these various crops do not necessarily move together, which reduces variability of overall farm income.

Growth in the organic sector has spurred government interest in the risk management needs of organic producers. The Agricultural Risk Protection Act of 2000 recognized organic farming as a 'good farming practice' that would be covered by Federal crop insurance. Federal crop insurance began covering transitional and certified organic acreage the following year under written agreements that included a 5% surcharge, reflecting USDA's uncertainty on organic yield variability. In 2004, organic practices were included in the basic provisions of the common crop policy of Federal crop insurance, making organic farmers eligible for a wider range of coverage options[16].

In this article, we present views, gathered in 2001 and 2002, from a wide range of organic farmers on their risks, risk management strategies, and their risk management needs. We analyze the organic farmers' views by categorizing them by sources and similarity to those in conventional agriculture, by evaluating how they are managed, and by suggesting ways in which effective risk management assistance can be provided.

Methods and Materials

In order to better understand risks and risk management in organic farming, we organized and conducted six focus-group discussions with organic farmers. We planned the discussions so that participants could identify and describe their risks, how they are managed, and their needs for risk-management assistance. Our research team developed a set of focus-group discussion topics prior to conducting the focus groups (Table 1). We distributed a written description of the research project and a questionnaire on farm characteristics to participants prior to conducting the focus groups. The same set of topics was used at all meetings to ensure consistency across the different groups.

Table 1. Topics for discussion at focus groups.

1 Why do you farm organically?
2 Trends and issues for organic agriculture
3 Identify risk factors in organic agriculture. Are these factors different from conventional agriculture? Which of these are most important?
4 How do organic farmers manage risk? Are these strategies different from conventional agriculture? Which of these are most important?
5 Suggestions for USDA-initiated risk-management tools for organic agriculture. Opinions, knowledge and experience regarding USDA's farm programs

We chose to use focus groups because they enabled us to interact with decision makers to better identify their risk-management needs. Organic crop insurance is very new for both the Risk Management Agency and the organic community and, in developing new products, it is important to be sensitive to the needs and attitudes of the target group. Edmunds[17] argues that focus groups are especially useful when testing new concepts and brainstorming for new ideas, both of which apply to organic risk-management products. Therefore, the use of focus groups enabled us to develop a rich understanding of the critical issues related to risk and organic farming.

Each session lasted about 2 hours, with 20–30 minutes spent on each topic. At least two research team members, in addition to the facilitator, were present to take notes. This allowed the facilitator to manage the session, to make sure that all farmers had opportunities to take part in the discussions and that the topics were well covered. Written comments were accepted from farmers who felt more comfortable expressing their opinions that way. Following the meetings, the notes of the research team were consolidated, creating a consensus description of the focus-group results.

The sessions were held between 2 November 2001 and 20 July 2002. Five of the six sessions were held at sites of conferences or workshops on organic agriculture, and one was held following a meeting of a farmer cooperative. Piggybacking our sessions with existing organic conferences allowed us to solicit participants through conference brochures, and it reduced the travel time for growers who were interested in participating. Conference organizers also advised us on the best timing for our focus groups and helped us target organic farmers for participation. Between 7 and 13 farmers participated in each session. Each participant was provided a $US100 honorarium.

We organized discussion groups in six states in different parts of the US, to capture some of the regional differences between organic farmers and the diversity of their operations (Table 2). Most participants had substantial farming experience, averaging 18 years farming, including 11 years farming organically. Most were 'full-time farmers', earning at least half of their family income through farming. Farmers in all of the groups except South Carolina raised some livestock.

Most of the participants at the South Carolina and New York meetings were market gardeners, who grew a diverse mix of fruits and vegetables on small acreages and marketed their crops locally. Their farms averaged about 40 acres, and South Carolina growers had somewhat less certified organic acreage (5 acres) than the New York growers (13 acres). A large part of their acreage was irrigated to ensure their production would meet the quality demands of their buyers. Most of these farmers sold their crops through a variety of direct and wholesale markets. More than half sold some of their produce through 'community-supported agriculture' (CSA) subscription service with consumers. Perhaps because they relied largely on direct markets, about 40% had not certified their farms as organic, but considered their farms functionally organic. Also, growers in South Carolina and other parts of the southern region may have had less access to organic certification services, because a number of nonprofit certifiers in the southern region were shifting their focus from certification to educational services during the study period and new groups had not yet taken their place[12].

In contrast to the market gardeners, the participants at the Texas and North Dakota sessions were field-crop producers and had a much greater area. Farmers in the Texas focus group averaged over 1500 acres (over 1000 acres certified organic) and specialized in producing organic cotton. North Dakota farmers grew field crops, such as small grains and various types of dry beans, and had an average farm size of over 2000 acres, nearly all certified organic or in transition. The farms in North Dakota were dryland operations, while three-quarters of the land in Texas was irrigated. Participants in the North Dakota and Texas groups sold most of their production through wholesale outlets.

The organic farms of the California and Wisconsin participants fell between the market gardeners and the field-crop producers in size. The California group was mostly vegetable, nut and fruit farmers, although an organic dairy farmer also participated. One of the California farms was a very large organic vegetable operation. The California farms averaged 166 acres, with 146 acres certified organic. The farmers at the Wisconsin session operated on farms averaging 290 acres, with 240 acres certified organic. Most of the Wisconsin participants had farm operations that were typical of the Corn Belt, with farming systems that included grain, soybeans, hogs and cattle. Several market gardeners, who sold their produce into Midwestern cities, also participated in the Wisconsin group.

Participants in all of the focus groups were dedicated to the land stewardship goals of organic agriculture, and were enthusiastic about their organic farming systems. One Midwestern farmer said that 'Organic farming taps awe and interest in learning and nature, and promotes human potential to learn more and know more'. More simply,

Table 2. Characteristics of farm operations of organic farmers participating in focus groups.

	Market garden		Crop/livestock	Vegetable	Specialized field crops	
	South Carolina	New York	Wisconsin	California	Texas	North Dakota
Farm description						
Number of farmers in focus group	11	13	12	7	8	11
Average farm size[1]						
Farm size (A)	36	42	289	166	1567	2099
Certified organic (A)	5	13	240	146	1036	1787
Transition organic (A)	1	6	25	0	90	139
Irrigated (A)	5	11	4	146	365	0
Average % of land that is owned	87	50	55	42	39	49
Farms with irrigation (%)	100	69	50	86	75	0
Farms without certification (%)	36	39	8	0	0	0
Average years farming	15	11	18	25	20	24
Average years farming organically	13	10	10	14	8	15
Farms purchasing crop insurance (%)	0	0	42	43	100	91
Farms receiving more than half of income from farming (%)	73	70	50	100	100	100
Livestock						
Farmers with livestock enterprises (%)	0	46	58	29	38	46
Marketing						
Farmers using direct marketing (%)	100	85	33	57	0	36
Farmers operating a CSA (%)	46	69	8	14	0	0
Farmers using wholesaling outlets (%)	82	69	100	100	100	91
Crop production						
Farms with fruits and vegetables (%)	100	100	42	86	63	73
Farms with ornamental crops (%)	46	31	0	14	0	0
Farms with field crops (%)	0	0	67	43	100	100
Farms with pasture and forages (%)	0	8	50	14	13	36

[1] An Olympic average was used because in the majority of the workshops there was one farm that was significantly bigger than the other farms in the focus group. A, acres.

The following associations helped arrange the six focus groups: the Carolina Farm Stewardship Association (South Carolina); the Regional Farm and Food Project (New York); the Midwest Organic and Sustainable Education Services (Wisconsin); the Ecological Farming Association and California Certified Organic Growers (California); the Northern Plains Sustainable Agriculture Society (North Dakota); and the Texas Organic Cotton Marketing Cooperative (Texas).

a California producer said that 'farming is fun again'. The Texas cotton farmers took enormous pleasure in proving to their skeptical, conventional neighbors that 'it could be done'.

Participants in all of the groups believed that by farming organically they protected water quality, soil vitality, biodiversity, and their families and customers. Many of the participants were especially concerned about farm worker and farm family exposure to chemicals. One of the Texas farmers said that he thought that the death of his father from leukemia was linked to exposure to agricultural chemicals.

The market gardeners noted that organic agriculture is more profitable for their small enterprises because they can tap the higher per-unit prices associated with organic products. A dairy farmer in California said that since transitioning to organic his profits were dramatically higher and his two sons had returned to farm with him. A wheat farmer in North Dakota noted with a smile that he likes '$7 wheat'.

Risk-management Results

This section consists of comments of the focus-group participants in response to our three questions on organic risk management, the main focus of this study. It is important to understand that focus groups are designed to identify qualitative information as opposed to quantitative data[17]. This precludes the use of quantitative analytical methods such as statistics, but provides first-hand information on the important issues affecting the target group. First-hand information on the risk-management issues of organic farmers is especially useful for our study because organic risk-management products are in the early stages of development.

We categorized and summarized comments on risk from the six focus groups into three sections that correspond with our three discussion questions on that topic (Table 1, questions 3–5): risks, risk management and risk-management assistance. We have grouped the comments into the categories that emerged in the discussions and

have attempted to report the full range of participants' comments.

Risks in organic agriculture

Production risks. Many of the organic farmers noted that weather and climatic risks are similar for organic and conventional farmers. A west Texas organic cotton farmer pointed out that in harsh climates, bad weather such as hail or wind can destroy a crop, whether organic or conventional, very quickly. Others pointed out that any farmer without irrigation faces the risk of drought, but that organic farmers' investment in soil quality allows their soils to hold water and withstand drought better than those of their conventional counterparts.

While diseases, insects and, especially, weeds can cause problems for organic farmers, most said that they use cultural practices to prevent pest problems from developing and to reduce risks from pests. Several noted that they can control pest problems that might develop on their farms, but that those that develop on other farms are a threat. A South Carolina farmer noted that this puts organic farmers decidedly at risk because they do not have quick-fix solutions, such as pesticides. A Wisconsin farmer said 'I use biologically-appropriate strategies to avoid problems on my farm; if I get problems coming on to my farm from the outside, there is very little I can do to control, mitigate, or prevent these problems'. Other organic farmers explained that crop diversification and timing of planting helps them withstand threats from conventional agriculture induced pests and diseases. However, a Wisconsin farmer noted that protecting against insects by late planting increases the risk of an early frost.

Several organic farmers said that they face less risk than conventional producers because they use non-chemical controls. They explained that pests can develop resistance to chemical controls and that developing new pesticides can be difficult. Organic farmers also noted that they are less restricted in their choice of crops for rotation than conventional farmers, who risk damage to certain crops from previously applied pesticides.

Several participants said that they do not agree with the claim that spraying by conventional farmers provides organic farmers with 'free protection'. They explained that buffer zones do not always protect against pesticide drift and that spraying often kills the beneficial insects that are necessary for pest control on organic farms. An organic farmer in Texas, for example, said that the widespread spraying for boll weevil has disrupted the supply of beneficial insects to the organic farmers.

Genetically modified organisms. Organic farmers at all the discussion sessions expressed considerable concern about risks from the use of genetically modified organisms (GMOs) by conventional farmers. Contamination from pollen drift from GMOs was seen as a particularly serious risk that could result in lost sales and lost organic certification. Many said that although buffer zones may help against pesticide drift, buffers may prove ineffective against GMO pollen drift.

Several organic farmers said that GMO contamination can come from anywhere. They noted that GMO contamination has been found in wild varieties of corn near the center of their origin in Mexico. Several participants at the North Dakota session recalled that a tornado in Canada led to contamination of canola with GMO pollen. Corn growers at the Wisconsin session thought that GMO corn pollen was already present everywhere. They explained that one way of managing the risk of GMO contamination was to plant their crop 1–2 weeks later than nearby conventional farmers, so that their organic crops would not pollinate at the same time as the predominant GMO varieties. They added that this strategy has only been modestly successful because cool and wet spring weather can delay plant growth such that corn plants pollinate at about the same time regardless of planting date. Several of the North Dakota organic wheat growers said they are taking a political approach, joining an effort to ban GMO wheat.

Organic farmers pointed out that GMOs may destroy the effectiveness of natural pest controls. For example, many organic farmers use Bt-based foliar pesticides, which are approved for organic use, to control insects. In recent years, transgenic varieties of corn containing the Bt protein have been developed, and organic farmers worry that their widespread use will hasten development of Bt resistance by insects and limit the usefulness of Bt organic pesticides.

Many of the organic farmers expressed a broad complaint about responsibility for GMOs. They explained that GMO companies provide a technology that is useless to organic farmers while, at the same time, exposing organic producers to substantial risks. Participants said that potential consequences of GMO contamination include loss of organic certification and markets, and could be very costly to them. Although none of the participants had yet lost certification due to GMO contamination, many were aware of farmers whose crops had been rejected by buyers due to GMO contamination.

Input risks. Organic farmers said that they face shortages of certified organic seeds, biological pesticides, specialized farm equipment designed for organic cultural practices and other inputs because the market they offer to suppliers may be too small to be served profitably by agribusiness. Also, New York market gardeners were particularly concerned about the drastic decline in the number of dairy farms in the northeast, and the loss of local sources of manure. Organic farmers also expressed concern about the availability of good-quality compost that has not been contaminated by GMOs. Some participants said that access to capital is a risk for organic farmers because banks are unfamiliar with organic production systems and have difficulty evaluating credit-worthiness. As a result, the flow of credit to organic producers is limited and can be difficult to obtain.

Organic farmers said that they, like some conventional farmers, are hurt by declining agricultural infrastructure

(i.e., farm equipment repair and service), shortage of good labor, and high prices for agricultural land due to suburban sprawl. They pointed out differences from conventional agriculture, noting that relocation costs are higher for organic farmers because they must re-establish their organic certification and work with a biological transition process that can last several years.

Organic marketplace risks. Organic farmers said that organic agriculture is expanding rapidly and is experiencing growing pains. Participants reported that price premiums are less stable and are dropping in some cases, and that niche markets, which have been developed over long periods of time, can disappear quickly.

For market gardeners, growing competition from larger farming operations is an increasing risk. Several said that large operations, which can provide retailers with large volumes of production, have tremendous leverage in the marketplace. Participants expressed a variety of concerns about competition, imports and oversupply in markets. New York organic farmers complained about large organic farms in California producing for markets in the northeast. California growers said that they were suffering from imports. They noted that countries such as China have cheap labor and that their organic certification may lack integrity. The Texas cotton producers also noted that their major competition is from countries with cheap labor.

Farmers participating in the Wisconsin session were concerned about consolidation in the food retailing industry. Some of the participants in a number of the focus groups believed that supermarket chains have no interest in using locally grown food. Many also felt threatened by a 'corporate approach' to organic production and processing.

Agricultural policy risks. Several organic farmers said that confusion about details of the National Organic Program rules—inconsistent interpretation of rules, uneven enforcement, and gray areas in certification—makes organic certification more tenuous. A Wisconsin farmer suggested that certification be completed in the winter months so that mistakes would be caught before they cost a farmer certification.

Some participants believed that the National Organic Program rules are based on stricter standards than those that state and private certifiers had implemented. For example, many market gardeners in New York and the Carolinas said that the new rules on certified organic seed, manure application and composting were stricter, and would make organic production more difficult. Others felt that the new rules are 'the lowest common denominator', which would reduce incentives to improve land stewardship. For example, a California dairy farmer said that large-scale dairy farms would pressure USDA to continue keeping pasture requirements loose, favoring large-scale dairies over smaller, pasture-based dairies.

Some participants pointed to a 'cheap food' policy by USDA as being detrimental to organic farmers. They said that cheap, chemical-intensive agricultural production does not reflect environmental costs, and is therefore sold below its true cost of production. Organic production, in contrast, includes these costs, and organic farmers are penalized by the perception of some consumers that organic food is too expensive. Focus-group participants also indicated that organic rotations include crops that might impose additional land requirements for organic farmers, and are not part of USDA's farm programs. Organic farmers, they added, typically do not operate using what they called 'the more you produce, the more you get paid' approach encouraged by USDA policy.

Several participants said that a lack of research on organic agriculture by USDA and universities is a risk in organic agriculture. They said that there is a major bias in the types of agricultural research undertaken because funding comes from chemical companies. Several organic farmers also pointed out that commodity associations often do not support organic agriculture, which can pose an additional risk for organic producers. One Wisconsin farmer noted, 'if the soybean association had an interest in farmers they would support agricultural producers. [Instead] they take our check-off dollars to drive us out of business'. Similarly, an organic cotton farmer indicated that organic farmers are required to pay dues to a marketing association that restricts the use of its seal on organic products.

Risk-management strategies used by organic farmers

Cultural practices. Most of the discussion group participants indicated that organic farming practices help them manage risk. They noted that organic crop rotations and crop successions increase organic matter, improve soil quality, buffer pH, manage pests and nutrients, and help hedge against bad weather. Several participants said that risk management and the satisfaction that comes from farming organically were sufficient incentives to farm organically. A Texas farmer explained, 'If we lost our markets (and price premiums) I don't know if we'd change our practices'. Participants noted that the smaller size of many organic farms makes risks easier to manage. A North Dakota farmer said that the higher 'eyes to acres' ratio of organic farmers enables them to see problems and correct them before they become more serious.

Diversification in crops grown was mentioned as an important risk-management strategy by market gardeners at the South Carolina and New York sessions. One South Carolina farmer noted that he ordered 148 seed items (different crops and varieties) in 1 year. Because of his multiple crops through the growing season, he simply replants if an early season crop was lost. Several market gardeners in South Carolina and New York said that they are adding high tunnels and greenhouses to extend their growing season and reduce risks of frost. Many organic vegetable and fruit farmers said that they irrigate to guard against production risks.

Several participants at the Wisconsin session said that they protect against production risk by growing several cultivars of the same species. These farmers said that they also grow open-pollinated crops and save seed as a way of developing sources of organic seed and varieties that guard against local diseases and pests. Several other Midwestern crop farmers said that they have re-introduced livestock into their operations, allowing them, in the event of a loss in crop quality and crop value, to feed their crop to their animals and then to sell the animals. These organic animal producers with pasture-based systems also said that they have seen a reduction in animal stress and disease problems, and an increase in animals' productive life spans on their farms.

Marketing strategies. Organic farmers mentioned that they manage risk by diversifying their marketing plans. Organic vegetable and fruit farmers, in particular, said that they market their crops through more than one channel. They mentioned community supported agriculture (CSA) arrangements, farmers' markets, small-scale markets and wholesale markets. Some farmers add value with a food-processing enterprise. The crop diversity involved in meeting organic rotation requirements also provides marketing advantages. Several organic farmers pointed out that economic losses suffered from early-season crop failure may be compensated for with economic gains from late-season crops.

CSAs provided an important risk-management strategy for many of the market gardeners at the South Carolina and New York sessions. A farmer participates in a CSA by selling shares or subscriptions to nearby consumers. The consumer shares in the risks associated with production, receiving more or less of particular products as weather patterns vary through the season. As one South Carolina farmer summarized it, 'the greater the importance of the CSA in the operation, the better the risk management'. Several organic farmers explained that CSAs build supportive relationships that increase consumer trust, leading to loyalty during hard times. One New York CSA farmer said that he has 'relationships, instead of insurance'. Another draws on a 'subsidy of goodwill' from the community.

Farmers in several of the focus groups had formed cooperatives as a way to manage market risks. The Wisconsin farmers who had expressed concern about the power of large retailers said that cooperatives are a way for farmers to control marketing. Participants explained that cooperatives had allowed them to raise capital for marketing expenses, such as the slotting fees needed to gain shelf space, and to gain marketing leverage. The Texas organic cotton growers had also formed a cooperative to help manage market risk. Their cotton production is pooled, helping to level out yields among farms, maintain markets, and gain economies of scale. Several of the organic cotton farmers explained that their cooperative efforts involve less dog-eat-dog competition than those of conventional farmers.

Mutual support. Many of the organic farmers participating in the discussions explained that they have formed support networks to help each other and to communicate with their consumers. They said that they actively promote locally grown organic agriculture—not just on their own behalf, but on behalf of their fellow farmers as well. These efforts have helped create consumers that stand by them during tough times.

Organic farmers said that they have tended to bond together more than their conventional neighbors. Wisconsin farmers agreed that organic farmers use group sharing and learning from others' experiences in an 'old fashion neighboring' spirit, where farmers share labor, machinery, ideas and information. They said that they also lobby together in the political process. One New York farmer stated that 'Organic farmers [have formed] a viable and exciting community against a lot of odds. The number of young people coming in [to farm organically] shows that organic agriculture has managed a lot of the risks that conventional agriculture has failed to manage'.

Needs for risk-management assistance

General programs. Several discussion group participants said that USDA needs to better support long-term research on organic farming systems, particularly systems for small farmers. It was also mentioned that land grant extension agents need to be retrained so that they can provide better service to organic farmers. One New York participant said that organic farmers need more extension programs and support, similar to that provided by the USDA-funded Appropriate Technology Transfer for Rural Areas (ATTRA) and the nonprofit Northeast Organic Farming Association in Maine. Several organic farmers said that consumer education programs about the quality of organic food and how organic production preserves and conserves farmland would help organic farmers.

Many participants noted that new organic farmers need help through the transition from conventional to organic. Several suggested educational programs to help farmers learn how to farm organically. Others suggested a short-term subsidy during the transition and assistance with the costs of organic certification. Other participants mentioned payments for fallowing land as part of an organic crop rotation, emergency relief for failing farms, protection against falling organic price premiums and low-interest loans for organic farmers. Several participants were troubled by talk of subsidies. One said that subsidies are a 'band-aid' approach to dealing with problems, and was joined by others who said that USDA should develop programs to eliminate problems so that subsidies would not be necessary.

Many participants, especially at the North Dakota and Wisconsin meetings, said that the government should require greater accountability by conventional agribusiness, in particular for damage from GMOs. Organic farmers mentioned that GMO firms should pay for testing of organic crops for GMOs and that the GMO firms should be held responsible for the loss in value of the organic

farmer's products due to GMO contamination. Several participants said that systems of grain handling need to be improved to separate and preserve the identity of organic crops. One Wisconsin farmer suggested that USDA establish GMO-free seed-growing regions, which would facilitate the development of organically grown seeds.

Crop insurance. Federal multiple-peril crop insurance, a major USDA program to assist farmers with yield and revenue risk, was discussed by all discussion groups. Producer experience with crop insurance was the greatest among organic field-crop producers, because federal crop insurance has been offered to field-crop producers for a long time. Federal crop insurance has only recently been offered to horticultural crop producers, and market gardeners in South Carolina and New York responded that they had practically no experience with crop insurance.

Organic field-crop producers participating in sessions in Wisconsin, North Dakota and Texas saw federal crop insurance as a risk-management tool that is workable but needs improvement. Several said that the problem with crop insurance is that the coverage does not reflect higher prices received for organically produced crops. They noted that the insurance 'price election' (the insurance value of a crop) is the same whether the crop is produced organically or conventionally, and is too low for organic farmers.

Some of the organic field-crop producers said that they would like the opportunity to buy higher amounts of coverage, even though this would probably mean higher premium costs. One farmer suggested that the level of coverage under federal multiple-peril crop insurance be established like it is under private hail insurance, allowing a producer to select a dollar amount of coverage without relying on expected yield and price election. A number of organic field crop producers in the North Dakota and Texas sessions criticized the federal crop insurance practice of charging a higher premium rate for organic production than for conventional production. Organic farmers in most of the discussion groups mentioned that federal crop insurance does not cover what they think is a major risk: the loss of sales and markets due to accidental contamination of crops from GMOs.

Organic farmers expressed interest in having crop insurance available for a wider variety of crops. Participants at the North Dakota session said that organic farmers have a problem getting coverage for the nonconventional crops, such as flax, that are part of their crop rotations. Also, participants at the North Dakota meeting mentioned that it is difficult to establish a production history, the basis of crop insurance coverage, when many different crops are grown each year for the rotation. A producer pointed out that county yield histories can be used in place of an individual farm's yield history, but that the county yield histories should be updated, and increased when appropriate.

The market gardener participants in the South Carolina and New York sessions expressed a general skepticism about the usefulness of crop insurance. None had purchased federal crop insurance. They said that other risk management practices are better suited to their operations than crop insurance. Several said that their crop and market diversification is their 'crop insurance'. One South Carolina farmer said that he would rather take his insurance premium money and invest in good irrigation equipment. Market gardeners also were concerned that price premiums for organic crops are not covered, and they thought that crop-by-crop insurance for their type of production system—which often includes 50 or more fruits and vegetables—could be impractical. Several of the market gardeners said they have an aversion to paperwork associated with insurance and other government programs. Several farmers expressed a perception that insurance programs cater to the 'big boys', and oversupply in markets was a greater concern for them than the risks covered by crop insurance.

A relatively new federal crop insurance product, Adjusted Gross Revenue (AGR), which insures whole-farm revenue rather than crop-by-crop yield or revenue, may be more useful for some farmers, especially those with many different crops[18]. Participants in the South Carolina, New York, and Wisconsin meetings discussed this too, and some expressed interest in this type of coverage. Others questioned how well AGR would work for new farmers or farmers planning an expansion.

Conclusions

Organic farmers participating in the group discussions identified a wide range of risks, management strategies and needs for assistance. They also raised issues about the equity of the currently subsidized risk-management programs, and they offered suggestions for crafting new programs. We have grouped their views on risk into three categories, depending on their similarity to conventional agriculture:

- risks that are similar to those in conventional farming, although they may be managed in different ways in organic farming;
- risks that are different between organic farming and conventional farming, but that may only be temporary, due to the recent rapid growth in the organic sector;
- risks that are greatly different from those of most conventional farmers because of the different nature of the production and marketing systems.

For risks that were seen as similar to those in conventional agriculture, organic farmers questioned whether they have the same access to the management tools available to conventional farmers. The organic grain and cotton producers had used federally subsidized crop insurance to manage these risks. They suggested that a number of modifications in crop insurance, including a higher price election that reflects organic price premiums and coverage for the more diverse set of crops in their

organic rotations, would increase its effectiveness for them. The organic specialty crop producers had far less experience with federally subsidized crop insurance, which has only recently been offered to this type of producer, conventional or organic. Some of the larger organic fruit and vegetable producers showed some interest in this tool, but market gardeners indicated that single-commodity crop insurance may not be practical for organic farms with a lot of different crops.

Some of the risks that focus-group participants described may only be temporary, such as the risks associated with the recent rapid growth in the organic sector. For example, national organic standards were developed in response to growth in the organic sector and are intended to facilitate marketing of agricultural products and assure consumers that consistent, uniform standards are met. However, gray areas have emerged in the implementation of these standards, and some participants were concerned that they could lose their certification unintentionally. While these ambiguities should be resolved over time, for now they are perceived as posing a risk to some organic farmers.

The process of transitioning from conventional to organic agriculture may also pose production and market risks that do not persist over time. During the transition process, farmers face a steep learning curve as they learn to control pests biologically, manage nutrient cycles, produce different crops and tap new markets. Crop yields may drop initially on some farms as the soil is being rebuilt and beneficial insect populations are restored. Farmers are unable to command organic premiums until after they have acquired organic certification, which usually requires a 3-year waiting period and can cost hundreds or thousands of dollars. Also, while the market for organic products is increasing rapidly, it is also immature, and some markets may be sensitive to oversupply and prices may be highly variable. Federally subsidized crop insurance may be especially important for some farmers during the initial transition period.

Focus-group participants also indicated that organic farmers face some unique risks that persist over time, which raises the issue of whether new risk-management tools are also needed. Organic farmers have developed a production system, now codified in federal standards, that is based on investments in soil building and agroecosystem health activities. They may be especially vulnerable to GMO and other contamination of their land, as well as their products, because many of their investments (such as investment in soil) are not transferable to land on other farms. Organic farmers expressed interest in new risk-management tools, such as crop insurance coverage for GMO contamination, which would address these risks explicitly. They also expressed strong interest in broader changes in the policy environment—such as a shift in public spending toward organic research, extension, and consumer education—which would enhance overall public support for organic farmers.

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When the apple falls close to the tree: Local food systems and the preservation of diversity

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Abstract

Agricultural industrialization, Green Revolution technologies, environmental change and civil conflicts have all been cited as contributing to the erosion of crop biodiversity. An additional factor is change in the characteristics of markets, including distance to market. Proponents of sustainable agriculture claim that one benefit of local food systems is the preservation of crop biodiversity. This paper explores that claim, examining Ohio orchardists' understanding and valuation of apple varieties and relating these to the preservation of biodiversity. Growers provided lists of apple varieties and then performed pilesorts on them. Analysis using multidimensional scaling reveals the underlying dimensions growers use to distinguish those cultivars. Salient characteristics are taste, use and market focus. Demands of the conventional commercial market with regards to transportation, appearance and storage exclude the old varieties. On the other hand, there is a strong congruence between sales in local markets and production of old varieties. Local markets, such as roadside stands and 'pick-your-own' operations, play an important role in the preservation of heirloom varieties of apples.

Key words: local food systems, crop biodiversity, apple varieties, sustainable food systems, heirloom varieties, niche markets

Introduction

Crop biodiversity is 'the biodiversity that people made'[1]. It is the result of millennia of selection for favorable traits, such as larger fruits, stronger stalks, earlier ripening and frost resistance. The result has been the creation of tremendous intra-species diversity of crops: thousands of cultivars of staple crops such as potatoes in the Andes, rice in South-East Asia, wheat in the Near East and maize in Mesoamerica, as well as countless varieties of fruits and vegetables.

The trend of expanding crop biodiversity is now being reversed. The shift in agricultural production and distribution systems towards greater commercialization, increased technological inputs and globalization has been accompanied by the rapid loss of crop biodiversity. The magnitude of the loss is substantial. In Indonesia, thousands of rice varieties disappeared in just a few years when the planting of local varieties was banned[2]. In China, the 10,000 varieties of wheat that were grown in 1949 were reduced by 90% by the 1970s[3]. This story is repeated with other major crops as well as fruit and vegetables. A study undertaken by the Rural Advancement Foundation International (RAFI) compared lists of varieties compiled by the USDA in 1903 (based on varieties being sold at that time by commercial seed houses) with varieties currently held in the US National Seed Storage Laboratory. Table 1 shows the extent of the loss for five vegetables, ranging from 81% to 95%; these numbers are typical of fruits and vegetables, for which the estimated loss of varieties during the 20th century was 80–90%[4].

In the face of rapid erosion of crop diversity, substantial effort has been given to the *ex situ* preservation of genetic material. Today, thousands of varieties of crops are maintained in storage banks throughout the world[5]. While preserving this genetic material is vital, its isolation from the functioning ecosystems in which it adapts and evolves is none the less problematic[6,7]. In addition, *ex situ* storage does not address the preservation of farmers' knowledge of landraces (crop varieties improved by farmers' selection rather than modern breeding techniques)[8,9].

In parallel to efforts surrounding *ex situ* preservation, attention has been given to understanding the range of on-site crop diversity, particularly among traditional

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Table 1. Loss of varieties and distance traveled to market, for selected vegetables.

Item	Loss of varieties since the end of 19th century[30]	Distance to market (miles)[25]
Carrots	95%	1838
Onions	94%	1759
Peppers	93%	1589
Tomatoes	90%	1569
Cabbage	81%	719

agriculturalists. The ecological benefits of maintaining such diversity are clear, yet our understanding of why farmers continue to use genetically diverse crops lags[10]. This is especially true in developed locales, where it is virtually assumed that the commercialization and industrialization of agriculture has resulted in monocrops.

The main cause of genetic erosion is presumed by many authors to be the widespread adoption of modern crop varieties in areas previously dominated by traditional varieties of the same crops[11–14]. Often—but not always[10,15]—modern varieties replace the array of traditional varieties, leading to the domination of crops by one or a few varieties[16]. While the newer (Green Revolution) varieties may be higher yielding, they also require higher inputs of fertilizers, irrigation water and pest controls.

Other explanations for why this loss has occurred (and continues to occur) have been offered. Among the factors cited are:

- Environmental changes, which may include precipitation shifts, depletion of soils, or changes in pest and disease threats. As a result of such changes, traditional crop varieties may no longer be adapted to growing conditions. This happened with rice in Senegal and Gambia, where several decades of below-normal precipitation led to the displacement of traditional varieties by improved ones that matured rapidly[3].
- Civil conflicts can have substantial impacts on crop arrays. Seed stores may be looted and seed networks disrupted[17]. Such conflict can also destroy harvests and create hunger. In response, farm families may be forced to eat seed stock, setting the stage for shifts in varieties.
- Changing labor markets can lead to decreased numbers of growers as farming people became full-time wage laborers. When this happens, the risk of loss of agricultural knowledge increases, including the loss of important skills such as seed-saving[18].

As a consequence of these processes, once-diverse crops are now dominated by one or a few varieties. As Durning[19] describes it 'crop fields, orchards, animal farms, tree plantations, pastures, fish runs—all have been turned into genetically-uniform super producers'. In the wake of the southern corn blight in 1970, US researchers established that 60–70% of the total bean acreage was planted with two to three varieties, 72% of the potato acreage contained four varieties, and 53% of the cotton land contained only three cotton varieties[20]. These monocrops are vulnerable to a variety of threats, including disease, pest infestations and unfavorable climatic events[6,18].

Yet another factor that can impact crop biodiversity is development of, and access to, markets. For example, in Andean farming systems, families plant diverse native potato varieties in scattered agricultural fields, both for different culinary purposes and as part of their response to risk[21,22]. However, this native diversity is not represented in the market system[23] and, indeed, the erosion of genetic diversity seems to be most severe where market involvement is greatest. Changing characteristics of the market system can also affect the preservation of crop biodiversity. One such characteristic is the distance food travels to market. As the geographic scale of our food system has increased, different characteristics of foods have become more significant. This factor will be the focus of the present paper.

Geographic Scale of the Food System

We begin by considering the geographic scale of our food system. The figure commonly cited is that the average morsel of food travels 1300 miles from the time it leaves the field (or pasture) and arrives on the table[24]. Recent work at the Leopold Center in Iowa generally confirms this figure as a reasonable average across many produce items (Table 1). Researchers calculated the distance traveled by a variety of produce items in the conventional distribution system—that is, items produced somewhere in the continental United States and then shipped to Iowa for consumption, and found an average distance traveled of 1494 miles[25].

In contrast to the conventional food system that operates on national and transnational scales, a movement towards the re-localization of food systems has gained prominence[26]. Wendell Berry[27] described such a system as: 'an economy in which local consumers buy as much of their food as possible from local producers and in which local producers produce as much as they can for the local market'.

A number of sustainable food system advocates have made the link between the distance food travels, on the one hand, and the loss of crop biodiversity, on the other. Norberg-Hodge[28], for instance, makes the argument that the process of globalizing our food supply has led to the disappearance of countless crop varieties: 'In the process [of globalization] ... Diversified food production for local communities is replaced by export monoculture for profit. Thousands of local plant varieties disappear'.

Others suggest explicitly that a benefit of local food systems is the preservation of crop biodiversity. Halweil[29], for example, states that 'Farmers producing for the local market tend to increase the diversity of their plantings'.

This is central to our examination. Our aim is to explore the claim that, in the face of rapid genetic erosion of crops, the re-localization of food systems helps maintain crop biodiversity. Key to this argument is the premise that when food crops do not have to travel far to reach their markets, farmers are free to select varieties for qualities other than their ability to withstand the increased handling and packaging, long-distance shipping, and prolonged shelf-life demanded by the distances traveled in the conventional food system. We will explore this issue in the context of apple diversity.

RAFI researchers documented a tremendous historical diversity of apples but an enormous loss as well. Between 1804 and 1904, 7098 varieties of apples were in use in the US. Of these, 6121 (86.2%) have been lost[30].

Against this backdrop, our goal is to answer this question: Do local food systems help preserve crop biodiversity, and if so, how? Our approach is to understand the characteristics by which growers distinguish and value different varieties. Growers, after all, are the ones making choices about whether or not varieties will be maintained[14,31].

Methods

To begin to answer our question, we worked with ten apple growers in Central Ohio who grew, on average, 25 different varieties of apples. As a first step, the growers were asked to name both current and old varieties of apples grown in the area. Respondents named 100 varieties as 'current' varieties and 64 as 'old' varieties. Apples named on the 'current' list are many that would be familiar to most US-based consumers, and include varieties such as Fuji, Golden Delicious and Gala. Named 'old varieties' include Cox's Orange Pippin, Rome Beauty and Winesap, all of which originated prior to 1850.

Table 2 lists the 33 varieties (both 'current' and 'old'), which were most frequently mentioned, their dates of origin or introduction, and the code used to identify each in subsequent figures. Included are those 'current' varieties mentioned three or more times, and 'old' varieties mentioned as least twice. We used these—the most frequently named varieties—for additional data collection.

We wrote the names of these varieties on index cards, one name per card. Each grower was visited and during the visit asked to sort the cards into separate piles, however many they deemed appropriate, based on similar characteristics. When done, they were asked to explain what characteristic described each pile. After this, the process was repeated with a second set of cards, instructing the grower to base the second sort on some different characteristic than the first time. This data collection method, called pilesorting, is a way to elicit information from respondents about their judgments of similarities and differences among a set of items[32]. The information collected in these pilesorts was then used in a multi-dimensional scaling analysis.

Table 2. Apple varieties used in pilesorts, code (used in Figs 1–3) and date of origin for each variety.

Variety name	Code	Date
Adam's Pearmain	n/a	1826
Braeburn	BURN	1952
Cortland	CORT	1915
Cox's Orange Pippin	OPIP	1830
Empire	EMP	1966
Fuji	FUJI	1962
Gala	GALA	1965
Golden Delicious	GDEL	1900
Granny Smith	SMTH	1868
Grimes Golden	GGLD	1804
Honey Crisp	HCSP	1991
Idared	IDA	1942
Keepsake	n/a	1979
Jonafree	JFRE	1979
Jonagold	JGLD	1968
Jonathan	JTHN	1826
Law Rome	LROM	1980
McIntosh	MC	1870
Melrose	MLRO	1944
Mollie's Delicious	MDEL	1966
Mutsu	MUTS	1948
Newton Pippin	NPIP	~1700
Northern Spy	NSPY	1800
Pink Lady	PLDY	1979
Red Delicious	RDEL	1870s
Rome Beauty	RBTY	1848
Russet	RUSS	1600s
Stayman Winesap	SWNS	1866
Wealthy	WLTH	1860
Winesap	WNSP	1817
Winter Banana	WBAN	1876
Wolf River	WRIV	1875
York Imperial	YIMP	1830

Findings: Multidimensional Scaling Analysis

Multidimensional scaling is a way to graphically represent the respondents' collective understanding of the similarities and differences among the sorted items. Based on a multidimensional spatial representation of the items, clusters of items regarded as similar can be identified, and the underlying criteria by which respondents distinguish items can be inferred[33]. In the present case we used the information we collected during the pilesorts for this analysis, relying on the computer program ANTHROPAC 4.0[34] to perform the actual calculations, which are based on estimates of Euclidean distances.

The lists of items contained in the piles created by each respondent were entered into ANTHROPAC. The program constructs a similarity matrix of inter-respondent correlation for each item sorted. This matrix is used to create a visual plot of the spatial relationships between items, where distance is a measure of similarity. Items that appear to be

clustered together are those that, in the aggregate, were seen to be similar by respondents. The challenge for the analyst is to understand the underlying characteristics that create the similarities and differences reflected in the visual representation. These characteristics create the N-dimensions of the graph. For example, if respondents were sorting breeds of dogs, characteristics that could make up these dimensions might be size and demeanor. These trends would emerge in the way the breeds are located on the plot in relation to each other. Breeds of similar size would be positioned in close proximity along the axis defined as size. Those with similar demeanor would be located close to each other along the axis defined as demeanor. Inferring what characteristic corresponds to each axis (or 'dimension') is the task of the analyst[35].

Although we collected 20 pilesorts in all, 13 were entered into multidimensional scaling for analysis. The sorts that were eliminated were done so because the characteristics used in the sort were very idiosyncratic (such as number of trees the orchardist had in each variety). Two apple varieties were also eliminated from the final analysis. Adam's Pearmain and Keepsake were eliminated because they were put in the respondents' 'unknown' pile a majority of the time. Thus, the final analysis was based on 13 sorts and 31 varieties.

When the analysis was run in two dimensions, an unacceptably high stress level of 0.17 resulted. Assessing 'stress' in multidimensional scaling analysis provides a measure of fit. A high stress level means that the representation of the data may be very poor or highly distorted[33,35]. In order to reduce the stress level, and increase the accuracy of the representation, the same data were run using three dimensions. This resulted in an acceptable stress level of 0.118. Thus the results from the three-dimensional analysis are used as the basis for the analysis.

Experts in their Fields: Growers' Understanding of Apple Varieties

The three dimensions we identified are termed 'taste', 'use' and 'market'. The last is most significant in understanding the role of local markets in the preservation of biodiversity. Because of the difficulty of representing three dimensions on the two-dimensional space of a flat piece of paper, the plots of these spatial relations are presented two at a time. Figure 1 will be used to discuss the dimension of 'taste', Figure 2 'use', and Figure 3 will be used to discuss 'markets'. Table 2 gives the codes used to plot apple varieties in these figures.

First dimension: taste

Qualities of taste runs on a continuum of Dimension 1, in Figure 1 plotted along the *x*-axis. At the left side of the plot are those varieties with desirable taste qualities, which are

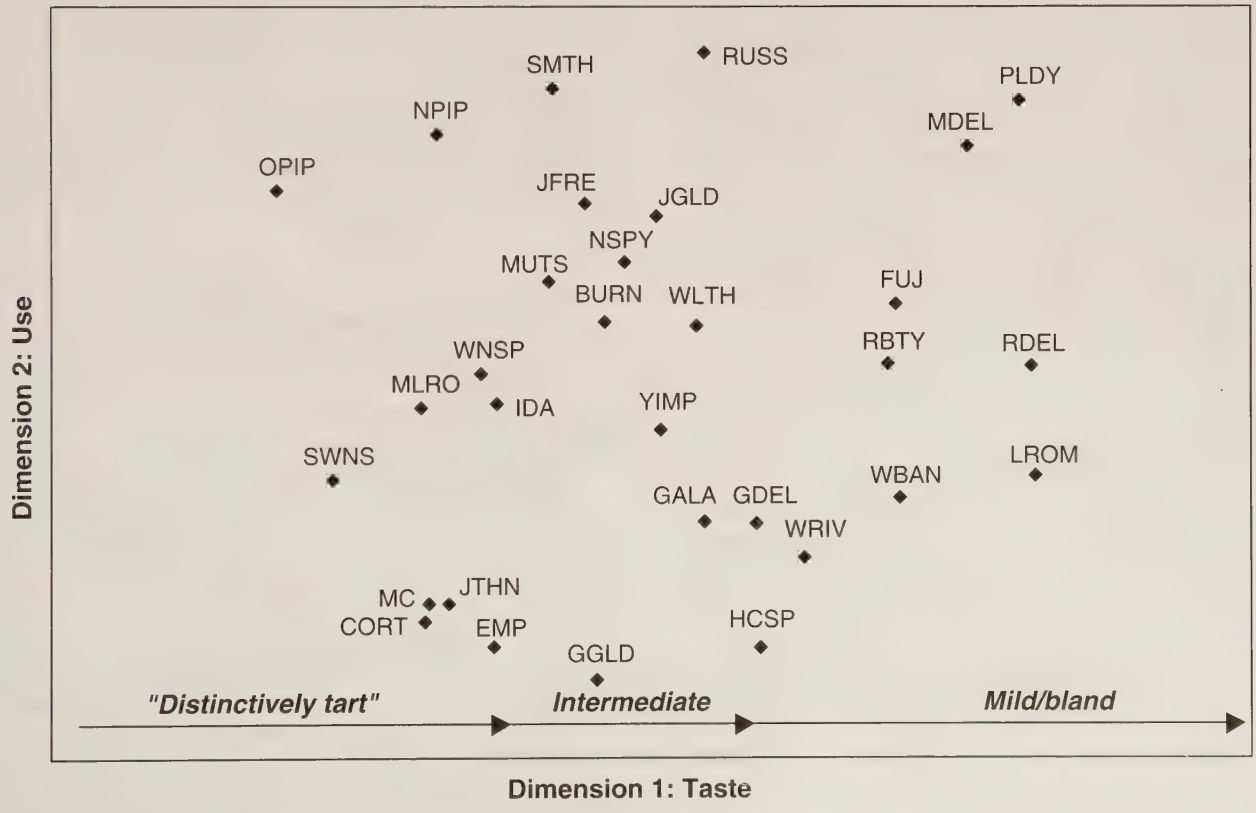

Figure 1. Results of the multidimensional scaling analysis: taste. The first dimension, taste, runs on a continuum from apples perceived by growers as distinctively tart to those regarded as bland.

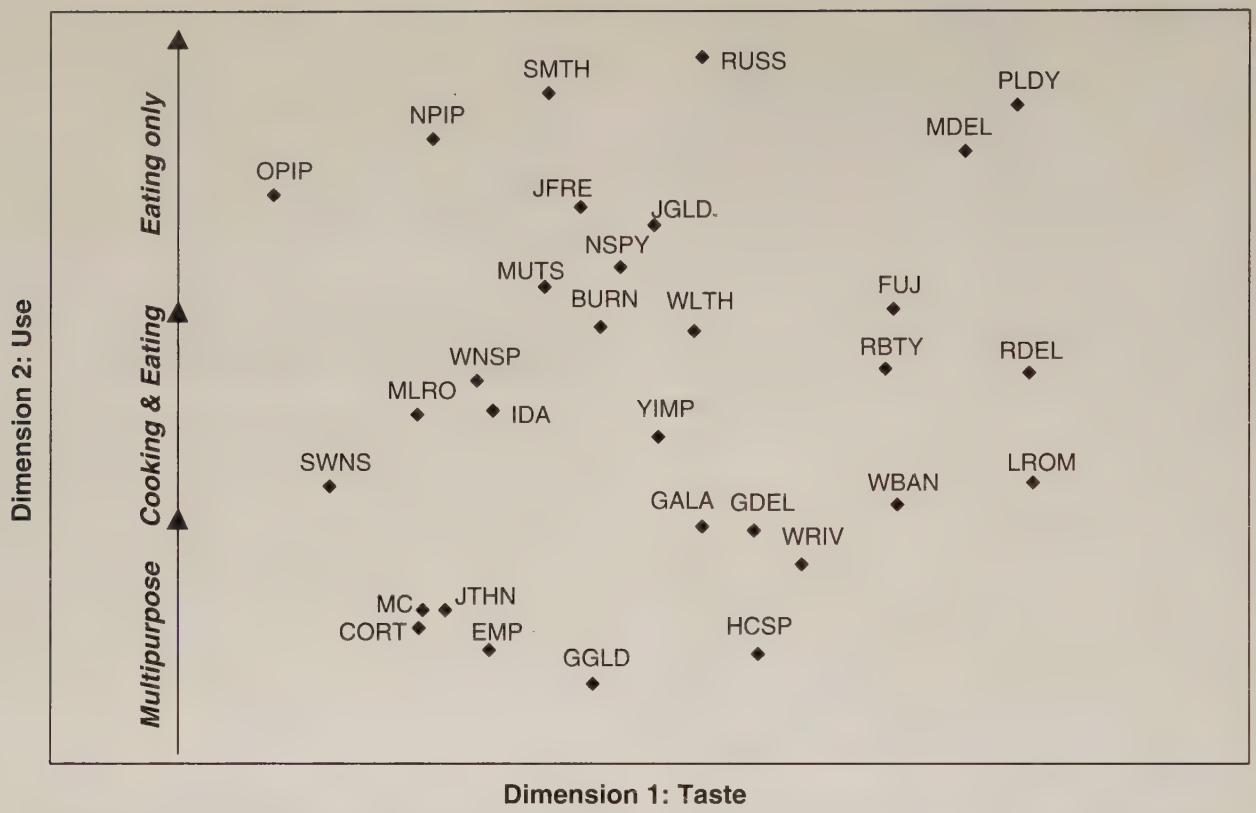

Figure 2. Results of the multidimensional scaling analysis: use. The second dimension, use, runs on a continuum from highly valued multipurpose varieties to those that can be used for eating only.

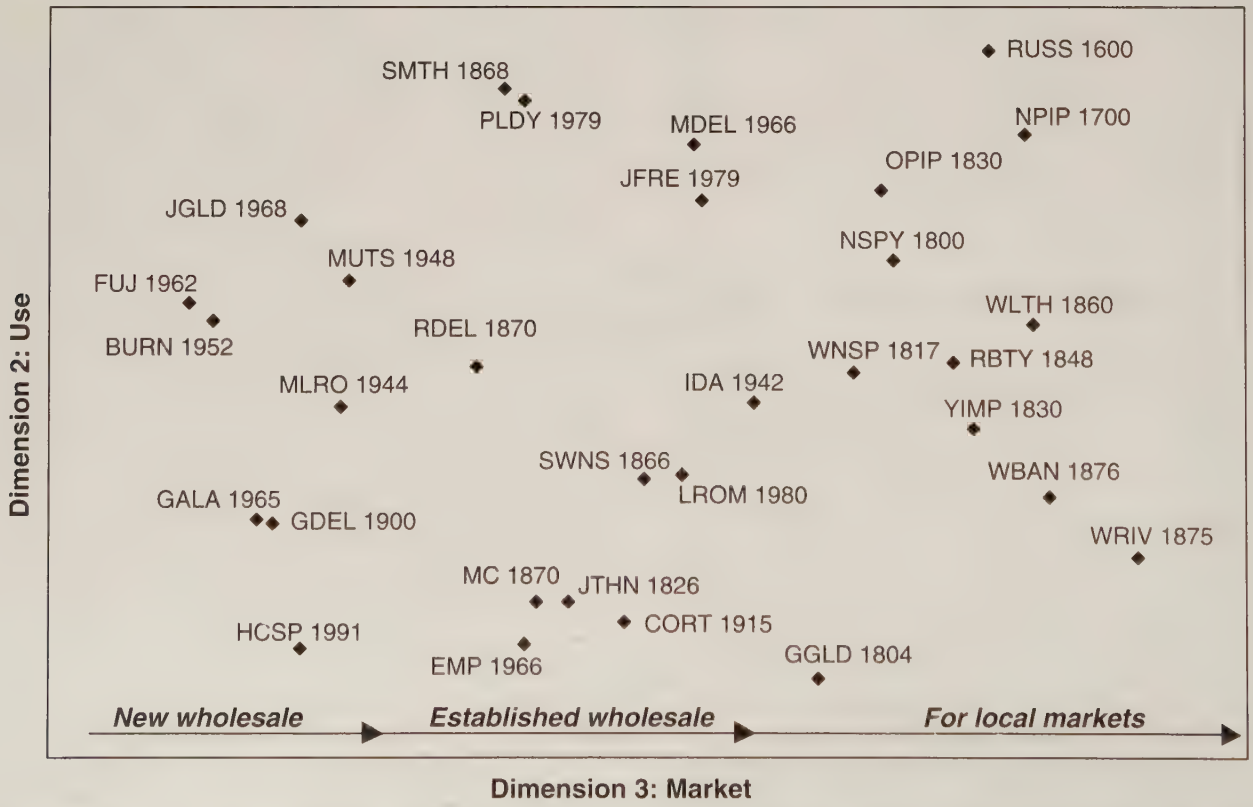

Figure 3. Results of the multidimensional scaling analysis: market. The third dimension, market, runs on a continuum from varieties emerging on the large-scale commercial market to those that are suitable for sale only in local markets. In addition to variety name, year of introduction is also plotted, illustrating that local markets provide the retail outlet for old varieties.

described by growers as a 'distinctive' flavor; varieties at the opposite (right) end of the scale are those considered to have an undesirable taste—described as mild or bland. In the intermediate range are tart-tasting apples, varieties described as a combination of tart and sweet, and sweet. In open-ended discussions, respondents emphasized tart as a more desirable taste than sweet.

Starting on the left, varieties such as Cox's Orange Pippin, Grimes Golden, Stayman Winesap, Cortland, McIntosh, Newton Pippin, and Winesap are described by growers as possessing distinct, flavorful taste. Stayman Winesap and Winesap are known for their tart, rich, wine-like flavor. McIntosh and Cortland both have similar tart, tangy, spicy tastes. Newton Pippin is characterized as having a taste that is rich with a piney tartness. Continuing, the varieties retain the tart quality, but are not described as being distinct. Granny Smith and Northern Spy are both extremely tart apples, but according to growers they lack the richness or distinctiveness of the varieties mentioned earlier; as such, their taste is not considered outstanding.

Moving on, tartness is replaced by sweetness with varieties such as Golden Delicious and Honey Crisp. Finally, at the end of the continuum are varieties that growers described as bland, including Rome Beauty, Red Delicious and Law Rome. One respondent described Rome Beauty and Law Rome as 'bad apples', and added that he didn't know why people even grow them.

Thus, Dimension 1 represents growers' values of taste among varieties, running on a continuum from those with distinctive tart tastes to those that are sweet or bland. Moving from distinct to bland, tartness levels decrease, reflecting most growers' preference for tart apples. The neat organization of varieties along this continuum demonstrates that the quality of taste is highly salient among growers.

Second dimension: use

The second dimension is the different uses for which varieties may be grown (plotted along the *y*-axis in Fig. 2). Respondents grow apples for eating raw, for cooking and for making cider. Varieties that can be used for all three are considered to be 'all-purpose' and are highly valued by the growers for their versatility and marketability. This includes varieties such as Grimes Golden, Honey Crisp, Cortland, McIntosh, Jonathan, Gala and Golden Delicious. These all-purpose apples are described by growers as having a 'dessert like' quality, making for good eating, but also retaining this quality when used for cooking. Cider processors also value these varieties, as they are used to produce quality cider. Jonathan and Golden Delicious are two of the cultivars most commonly used in Ohio apple cider blends, explaining, perhaps, why these are the among the varieties most commonly found growing in Ohio's apple orchards (they are grown in 94% and 81% of orchards, respectively)[36].

Continuing along the *y*-axis, there are varieties that are well-suited for cooking and eating, but not for processing. Winter Banana, Stayman Winesap, Winesap, Rome Beauty, York Imperial and Wealthy are all valued for their outstanding cooking characteristics, and are also quality eating apples. The ability to keep its shape when cooked is an important factor in a cooking apple; not being too sweet is also important. Having a slightly tart flavor allows the cook to add sugar to the desired sweetness; apples that are already sweet cannot be made less sweet. Thus their cooking and eating appeal makes them valuable to the grower for he or she can market them to those who want both an eating and cooking apple.

As their value as cooking apples decreases, what remains are those varieties appreciated only for their eating qualities. These varieties are less profitable for the grower because they have more limited marketing appeal. Varieties such as Red Delicious, Fuji, Mutsu, Mollie's Delicious and Granny Smith fit this category. Even though they can be, and sometimes are, used in other capacities, they are categorized as mainly eating apples. Thus, to the grower they are less valuable in terms of the range of purposes for which he or she can sell them.

Thus, this dimension reflects how growers value apples based on their uses: varieties that are suitable for multiple purposes (eating, cooking and cider processing) are most valued. Those that are suited only for eating are less valued because of the way their limited use restricts market possibilities.

Third dimension: market

Our interpretation of Dimension 3 centers on the market in which each variety is sold. Throughout interviews, the issue of markets and how they affect the types of varieties that a grower produces was a recurring theme. This, we believe, is key in understanding how apple varieties may be preserved. Growers distinguish between the varieties grown for the wholesale or 'commercial' market and those grown for the local (or 'niche') market. The latter includes 'pick-your-own' (u-pick) sales, farm markets and roadside stands; this distinction is echoed by other studies[37,38]. Growers' comments indicate that specific qualities make a given apple variety more suited for one market outlet or the other.

Appearance. Appearance is one such characteristic. On the wholesale market, apples have to look good, especially the color and texture of the skin. Color, for instance, should be even and vivid. As early as 1933, researchers at the Ohio Agriculture Experimental Station observed that the demands of the market had shifted the value of some varieties, citing Grimes Golden as an example. This apple, they claimed, 'has within the last 2 or 3 years met serious sales resistance because of its color'[39]. Likewise, apples with easily bruised skins or skin that has a speckled, or russeted, appearance can't be sold to this outlet. On the other hand, in the local markets growers are able to sell

apple varieties that are not as 'perfect' in appearance. One grower proclaimed that 'we ship beautiful mediocrity' to note his judgment that the apples sold wholesale were pretty to look at, but inferior in other qualities.

Resistance to bruising. This is a second important characteristic of apples sold commercially, as they will need to be shipped, sometimes long distances. Because they will be handled heavily in the process of packaging, transporting and displaying, only varieties resistant to bruising can be marketed this way. Apples that are sold on-site are not exposed to these conditions. They are simply picked and stored locally until they go into the hands of the customer—or in the case of u-pick, it is those same customer hands that do the picking. The minimal amount of handling means that varieties sold in this way can be more susceptible to bruising without adverse effect.

Keeping quality. The ability to store well is also a factor. Varieties sold wholesale are generally neither stored nor displayed in highly refrigerated areas, so must be able to keep reasonably well without constant refrigeration. The waxy coating characteristically found on wholesale apples is applied in order to hold in both temperature and moisture, but even with this measure some varieties cannot be kept under non-refrigerated conditions for extended periods of time. Many locally sold varieties, on the other hand, are generally offered on a production basis: they are sold soon after being picked and therefore are not subject to the same storage requirements.

These differences can be used to interpret the organization of varieties along Dimension 3 (the *x*-axis in Fig. 3). This dimension is organized along a continuum from varieties that have strong wholesale market potential—because they possess these qualities—to those that only have a viable place in local marketing schemes.

Varieties such as Fuji, Gala and Braeburn are considered to be new varieties by growers, and are described in forecasts as the 'key ''new'' cultivars'[40]; they are up-and-coming in the wholesale market, meeting its demands for appearance, hardiness and keeping. Another such apple, Melrose, recently became the official apple of Ohio. This title has brought increased name recognition for the variety and thus more large-scale market appeal.

Further along Dimension 3 are varieties that are already well established in the wholesale market. Red Delicious, Granny Smith, Empire, McIntosh, Jonathan and Cortland are among the most popular and well-known commercial varieties; and these varieties conform to the characteristics required by the wholesale market.

Varieties such as Grimes Golden, Cox's Orange Pippin, Northern Spy, York Imperial, Russet, Newton Pippin, Wealthy and Winter Banana are located at the end of this continuum. Many of these old varieties are not attractive enough to be viable in the wholesale market. Russet, for example, is named because of the appearance of russet spots on its skin. Cox's Orange Pippin has a dull finish and thin skin, which is not suited for rough handling. Northern Spy, York Imperial and Newton Pippin are all flat or squat in shape and have uneven greenish-yellow areas. These were once important varieties in orchards, but they have lost their place as the value of appearance and hardiness in transport increased with larger, and more distant, markets. However, these last varieties still have an established place in local markets.

Importantly, Figure 3 also shows the year of introduction of each of the varieties. In general, there is a gradient from relatively recent introductions to old varieties, those that originated during the 18th and 19th centuries. Of greatest importance are those on the right-hand portion of the graph, where these old varieties are clustered, corresponding to the use of local markets. This pattern underscores the point, voiced both by growers and sustainable food system advocates, that local markets preserve crop biodiversity.

Conclusion

> The reduction in the number of apple varieties grown and the pursuit of the ideal 'commercial' apple has slowly and insidiously changed our perception of the fruit itself[41].

For Ohio apple growers, qualities of taste, use and market destination are key in their understanding of, and decision-making about, apple varieties. Varieties that are regarded highly for their taste qualities or versatility of use are not necessarily those regarded for commercial market potential. This reflects the demands placed on apples in the commercial market (for appearance, for durability, etc.), which contrasts with the way(s) in which growers value the apple varieties. When marketing on the local level, the main criteria that growers apply in choosing varieties are taste and use. Of the growers who sell on the commercial and local level, most of them expressed a preference for the local markets because they can apply their own values in deciding which varieties to grow.

Our conclusion is that local food systems do help preserve apple biodiversity. Many of the old apple varieties cannot participate in the conventional market system because they do not meet its standards of appearance, they bruise too easily and they are unable to withstand the transport and storage demands. Local markets thus give growers the freedom to select the varieties they produce, based on their own valuation of these varieties, rather than those dictated by the commercial market. In essence, we can look at local markets as refuges for the old varieties; in the absence of local markets, many of the older varieties would no longer be grown.

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Influence of farm management style on adoption of biologically integrated farming practices in California

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Abstract

We consider the adoption of biologically integrated agricultural practices from the perspective of farm management style. Adoption decisions for farming practices must fit into a broader farm decision-making context that incorporates economic, environmental, social, family and personal considerations, as well as use of agricultural information sources. Drawing from a study of California almond and winegrape growers, we demonstrate that management styles differ substantially among farmers, these differences affect use of information sources and adoption of biologically based practices on the farm, and such adoption does not negatively affect crop performance. We used Q-methodology, a method for eliciting qualitative data using a variant of factor analysis, to identify three distinct management styles among a purposive sample of 40 growers. The Environmental Stewards' management style places higher priority on conservation of natural resources than on getting the highest possible yields or profits. Production Maximizers, with a different style, prioritize more traditional goals of producing the highest possible yields and quality and focusing resources on the farm rather than on outside concerns. Networking Entrepreneurs, on the other hand, value learning about innovative techniques in social contexts such as informational field days, evaluate new information with a business-like attitude and enjoy off-farm interests. A two-season mail survey of farming practices and information sources demonstrated that differences in management styles affect the adoption of practices. Environmental Stewards were more likely to practice biological pest control and encourage wildlife and less likely to use the most toxic chemicals. Production Maximizers had a greater tendency to use prophylactic and broad-spectrum chemicals, while Networking Entrepreneurs preferred more innovative biological pest controls but tended to avoid time-consuming cultural practices. Production Maximizers were distinguished by less use of more social forms of communication, such as attending field days and talking with other growers. Crop health and quality indicators showed that almost all growers were managing their crops very successfully, regardless of management style or choice of practices. These results hold important implications for efforts to increase the adoption of sustainable agriculture, especially by showing that contents and methods of outreach efforts must vary to accommodate diverse farm management styles.

Key words: sustainable agriculture, integrated pest management, farm management style, Q-methodology, pest control advisers (PCA), extension, adoption, almonds, winegrapes

Introduction

The term 'biologically integrated farming systems' was coined by Dr Robert Bugg (personal communication, July 2003) and is modeled after the term 'integrated farming', as commonly used in Europe. The term refers to more than just specific management practices; it implies a whole-systems approach that considers the impact of management practices on all organisms and ecological relationships in the farming system. This approach is contrasted to

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'conventional farming', which we interpret here as an approach that attempts to manipulate and control single elements in order to modify the agroecosystem and to counteract or eliminate perturbations, rather than to work *with* the system in an adaptive orientation.

Since the advent of formal programs of biological pest control, integrated pest management (IPM) and soil conservation techniques, an extensive body of literature has focused on issues of adoption of such techniques. Following a tradition of research in diffusion of innovations[1], studies typically try to find correspondence between the use of certain practices and one or more categories of farmer characteristics, including demographic and socio-economic characteristics, and information sources used[2–9]. While some authors have additionally examined farmers' attitudes and perceptions, to our knowledge no previous studies have attempted to integrate these diverse factors into a holistic management style.

A focus on management style directs attention to the decision-making process itself, as management style is defined by the sum of the decisions taken by a farmer and the priorities expressed in those decisions. Ajzen and Fishbein[10] maintain that empirical studies of many different types of behavior have shown time and again that what they term 'external variables', such as demographic characteristics and personality traits, tend to have few or weak relationships with actual behavior, although they may influence attitudes. Instead, Ajzen[11] proposes a theory of planned behavior, which states that the immediate determinant of a given action is a person's intention to perform or not to perform that particular action. Intention, in turn, is a function of personal attitudes (positive or negative evaluations of behaviors) mediated by subjective norms (what a person thinks others want him or her to do) and perceived behavioral control (the belief that one has the necessary resources and capability to perform a behavior). Attitudes, in turn, are determined by beliefs, which are associations of various attributes to an object or action.

Following such an approach, this study focuses on farmers' beliefs, attitudes and goals in order to understand adoption of specific practices. From the perspective of farm management, we can interpret the work of Ajzen to imply that beliefs and attitudes affect overall management goals. These goals, which incorporate economic, environmental, social, family and personal considerations, interact with available human and material resources and lead to the formulation of adaptive strategies to meet those goals. All these adaptive strategies together constitute a management style. Finally, management style is a direct determinant of particular decisions, or intentions, to adopt or not to adopt specific farming practices. This paper draws on data from California almond and winegrape growers to explore the diversity of management styles among growers, the effects of these diverse styles on adoption of biologically integrated farming practices and use of information sources, and the impact of adoption on crop performance.

Research Methods

Study design and sample selection

For the purposes of this study, indicators of adoption of biologically integrated farming were drawn from the suites of practices recommended by two related programs: the Biologically Integrated Orchard Systems (BIOS) program of the Community Alliance with Family Farmers (CAFF), and the Biologically Integrated Farming Systems (BIFS) program of the Lodi-Woodbridge Winegrape Commission (LWWC). BIOS was launched in 1993 by CAFF, a non-profit organization based in Davis, California, to integrate the expertise of growers, researchers, University of California Cooperative Extension farm advisors and state-licensed pest control advisers (PCAs) in providing assistance and support to almond growers wishing to reduce synthetic fertilizer and pesticide use[12]. BIOS-recommended practices hinge on using a whole-systems approach to building overall orchard health and buffering orchards against pest outbreaks. They include practices such as comprehensive monitoring of pest and beneficial populations, enhancing habitat for beneficials, releasing beneficials, cover cropping, applying natural fertilizers such as compost, using selective 'soft' pesticides such as *Bacillus thuringiensis* and only when monitoring indicates they are needed, and careful mowing and irrigation management for disease control.

The BIFS program, which encompasses several crops, grew out of the success of the initial BIOS program in almonds. In 1995, the LWWC, a grower-funded commission in California Crush District 11, received a BIFS grant to establish a grower–university partnership to identify and implement among member growers a similar set of BIOS-type practices for winegrapes, with some crop-specific modifications such as leaf removal for disease control.

The study sample comprised 40 farmers growing perennial crops, including 21 almond growers and 19 winegrape growers, in California's Central Valley. Within each crop, we selected a group of farmers practicing biologically integrated farming and a group of conventional farmers, on the basis of their participation or non-participation in the BIOS (almonds) or BIFS (winegrapes) programs.

Nine almond growers in Merced and Stanislaus Counties who are enrolled in the BIOS program were selected for this study. Twelve almond growers not participating in BIOS were also selected from Merced, Stanislaus and San Joaquin Counties. In winegrapes, this study included 11 growers actively participating in the LWWC BIFS program, and eight growers further south in San Joaquin County who were not part of the LWWC nor of the BIFS program.

Identifying farmer management styles using Q-methodology

In the first phase of the project we used Q-methodology to identify distinct management styles among the growers. This methodology has been applied previously to an

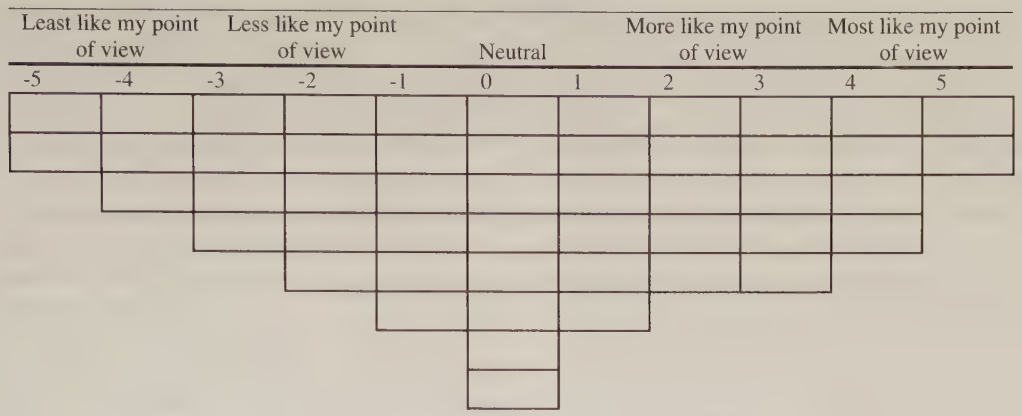

Figure 1. Statement sorting board.

agricultural context by Fairweather and Keating[13]. This approach inverts the rows and columns in a typical factor analysis. This inversion turns the focus of the analysis *towards* intercorrelations of people, based on each individual's overall pattern of all traits tested for, and *away* from intercorrelations of individual traits, based on how many people were tested for them[14,15]. By so doing, it enables the quantitative study of small sample sizes and even single cases, because the study population now becomes the set of tests or questions, rather than the set of people being tested.

The methodology also encompasses a particular method of data collection, which is designed to minimize interference from researcher bias by involving the respondent in a card-sorting exercise. In our study, each grower was given a set of cards, each printed with a goal or value statement relating to farm management. The grower then arranged the cards on a sorting board (Fig. 1) according to degree of agreement or disagreement with the selected statements. The statements were designed to test for growers' values, beliefs, attitudes and goals regarding factors ranging from economic factors (profit, stability and growth) to considerations for family, leisure, work environment, community involvement and social responsibility regarding environmental stewardship. The consequent rankings of statements from all growers were then analyzed using a Q-methodology software package, PQ Method[16], that identifies key suites of statements (or 'factors') ranked similarly by distinct groups of growers.

Farming practices and information use survey

In the second phase of the project, the same growers completed a mailed survey on information sources used, farming practices and financial and business aspects of their farms. The survey was administered twice, once after the 1998 growing season and again after the 1999 season. The over 50 items on farming practices called for simple yes/no responses to questions of whether or not the specified practices were used on any orchard or vineyard within the previous growing season. As such, the questions were designed to test for overall adoption of a practice and did not distinguish intensity or extent of use of a practice. The practices selected cover a wide range of functions, with particular emphasis on pest management (insect, mite, disease and weed), as well as fertility management, orchard/vineyard floor management, pruning/brush management, irrigation, and wildlife habitat enhancement.

The survey also asked growers to indicate their frequency of contact with various information sources. Personal contacts comprised Cooperative Extension farm advisors, crop handlers/buyers, as well as other growers/family members/neighbors. Independent and input-supplier-employed pest control advisers (PCAs) were also included. PCAs are state-licensed consultants who scout growers' fields and recommend pest control measures and, in some cases, fertilizer regimens. Input-supplier PCAs are open to conflicts of interest, since they typically recommend pesticides sold by their companies. In addition, they may have less extensive knowledge of biologically integrated approaches, as such knowledge is not currently a requirement of licensing. However, they do not charge growers directly for their services (although costs are included in the costs of the pesticides), while independent PCAs, many of whom specialize in biologically integrated pest control, contract with growers for a fee. Other media sources included manuals produced by the University of California Integrated Pest Management Program, other university publications, farm advisor newsletters, BIOS and LWWC publications, meetings/seminars/field days, Internet and trade journals.

Surveyed growers were asked to indicate weekly, monthly, annual or no frequency of use for each of 12 specified information sources. Farm-advisor members of the project team helped to standardize the raw frequency data to a three-level rating system that indicates high, moderate and low degree of use, allowing comparison of information sources that are typically available to farmers at very different frequencies (such as semi-annual field days versus a monthly publication).

Standard statistical techniques for hypothesis testing were not appropriate for our small and purposively selected sample of growers. Instead, we used Kendall's tau b, a measure of mutual association for ordered, categorical

data[17]. This measure is less sensitive than others to choice of response categories, which allowed us to assess relative differences between small groups of growers over a somewhat large number of response categories. Standard statistical significance levels are not associated with tau b results. We also used correspondence analysis to explore relationships between diverse variables. Correspondence analysis uses principal components analysis to transform matrices of categorical data into a graphical format, in which relationships between variables can be observed, based on physical proximity to each other[18].

Crop performance measures

We measured crop-specific biological performance for participating farmers. In almonds, leaf nutrient analysis and nut reject levels at harvest told us about the health of the trees and the impact of pests on the final crop quality and yield. For winegrapes, the key measure was the ratio of crop yield to weight of vine prunings taken during the following dormant season (also known as vine balance), which is an indicator of vine vigor and capacity for long-term sustained yield. A ratio between four and eight is generally considered desirable; a larger value indicates that the vine is probably being stressed to produce too much for long-term health, while a lower value indicates that the vine is not producing well or is overly vigorous in vegetative growth, at the expense of fruit production. Fruit from overly vigorous vines tends to produce lower-quality wine.

Results and Discussion

Demographic characteristics

The majority of growers in the sample had at least some college education, and while their ages ranged from younger than 35 years to about 75 years, 65% were over 45 years old. Their farms ranged from 6 to 2632 ha (mean 358 ha, median 57 ha). Our sample size was too small to identify statistically significant demographic differences between the groups described below.

Farmer management styles

The Q-method procedure resulted in three groups of growers, signifying three distinct management styles, which together accounted for 48% of the total variance. We named the three groups the Environmental Stewards, the Production Maximizers and the Networking Entrepreneurs, based on the statements each group most agreed or disagreed with.

The defining characteristic of the 17 Environmental Stewards (eight almond and nine winegrape growers) was a high valuation of environmental stewardship. They placed higher priority on managing resources in cooperation with nature than on getting the highest possible yields or profits. The Environmental Stewards were the least concerned with how they compare to other farmers in their communities, except on issues of crop quality, and they considered themselves more dependent on family help on the farm compared to the other groups.

The 14 Production Maximizers (seven almond and seven winegrape growers) focused most of their resources on their farm businesses and on producing the highest possible yields and quality. They took a more industrial approach to farming, with some expressing the view that they struggle with nature to get the best possible crop. Strongly committed to their farms, they were the least interested in off-farm activities, including exchanging information with others at events such as field days.

The nine Networking Entrepreneurs (six almond and three winegrape growers) distinguished themselves by placing relatively less emphasis on earning a living from the farm and showing a correspondingly stronger interest in off-farm activities and social interaction. They also valued new, cutting-edge information and enjoyed acquiring such information in social contexts such as extension field days and conversations with other farmers. Finally, they displayed a strong business-like attitude in their decision-making style, with considerations about the benefits of new farming techniques versus their costs in time, money and crop quality figuring highly in the Entrepreneurs' approaches to farm management.

Adoption of alternative and biologically integrated practices

Most and least commonly used practices. To provide a context for highlighting key differences in the adoption of farming practices, we begin here by outlining the similarities, i.e., farming practices that tended to be used by the majority of growers across all styles, as well as those practices that very few growers used. Most growers in the study employed practices that used standard materials more efficiently or carefully, such as spot spraying herbicides and managing irrigation and fertility to meet pest control goals (Table 1). Such practices can save money and reduce environmental stresses, while not requiring fundamental changes in pre-existing patterns of farm management.

In addition, almond growers in this study were characterized by their widespread use of foliar nutrient sprays, winter orchard sanitation for insect pest control, and burning of orchard prunings. They also maintained their orchard floors by mowing resident vegetation and avoiding or reducing tillage, which can be a money-saving strategy. Most winegrape growers, on the other hand, disked for weeds and use pre-emergent herbicides.

Several practices with very low rates of adoption among the study growers are relatively new. Fewer than 20% of almond growers had adopted reduced pruning (alternate year or no pruning) or pheromone use for peach twig borer control. Winegrape growers exhibited low adoption (fewer than 20%) of beneficial insect and mite releases for pest control and low use of compost for disease and pest

Table 1. Farming practices used by 80% or more of all growers (almonds and winegrapes) in both years surveyed.

Biological Pest Control
Monitoring insect pests
Monitoring mite pests
Cultural Pest Control
Dust reduction for mite control
Irrigation management for mite control
Irrigation management for disease control
Fertility management for disease control
Spray for disease based on weather
Biologically Integrated Floor Management
Spot spraying of herbicide for weed management
Conventional Floor Management
Use of contact herbicide for weed management
Fertility Practices
Use of synthetic fertilizers

Table 2. Grouping of farming practices into seven categories.

1. Biological Pest Control
Monitor beneficial insects
Monitor predatory mites
Cover crops for beneficial insects
Cover crops for predatory mites
2. Cultural Pest Control
Remove and destroy mummies
Compost for disease/pest suppression
3. Reduction of Toxic Chemicals
'Softer' or less toxic insecticides
Below label rate applications of insecticides
Alternate-row spraying of insecticides
Below label rate applications of miticides
Spraying 'hot spots' with miticides
Spraying for disease according to crop history
4. Biologically Integrated Floor Management
Minimum or no tillage
Hoeing, flaming or irrigation weed management
Seeded cover crop
Resident vegetation
Chip/shred/mulch prunings
5. Wildlife Habitat Enhancement
Owl/bat/bird boxes
Creating wildlife habitat
6. Prophylactic and Synthetic Chemicals
Broad-spectrum insecticide sprays
Routine spray for mites
Routine spray for disease
7. Conventional Floor Management
Pre-emergent herbicides
Disking
Maintenance of a 'clean' (bare) floor

suppression. They also had little adoption of electrostatic sprayers (which help sprays reach their target and avoid drift). Of the more traditional practices, very few winegrape growers burnt prunings, which would contribute to air pollution. Instead, they tended to shred prunings. Fewer than 20% of the almond growers maintained a 'clean' or bare orchard floor, which is the less ecologically integrated approach to floor management.

In order to better conceptualize and analyze differences in the adoption of farming practices, we reduced the total number of practices by eliminating those used by 80% or more of all growers, those used by 20% or fewer of all growers, and those that were specific to only one or the other crop. We then grouped the remaining practices into the following seven functional categories: Biological Pest Control, Cultural Pest Control, Reduction in Toxic Chemicals, Prophylactic and Synthetic Chemicals, Biologically Integrated Floor Management, Conventional Floor Management and Wildlife Habitat Enhancement (Table 2).

Differences between management styles. A preliminary assessment using multiple correspondence analysis to relate categories of practices to each other and to the three management style groups, using only 1998 data, reveals a distinct pattern. To represent this relationship graphically, growers were assigned raw scores denoting how many practices they had adopted within each category. We then calculated the mean score of all growers for each category, and assigned each grower a score of 1 in each category for which the raw score was greater than or equal to the mean score for that category, and a score of 0 when the raw score was less than the mean score. We performed a multiple correspondence analysis on this set of final 1/0 scores and plotted the results (Fig. 2).

As the graph illustrates, all the biological and biologically integrated categories of practices cluster together, and the two more 'conventional' categories, namely Conventional Floor Management and Prophylactic and Synthetic Chemicals, form their own separate cluster. Categories that are clustered together indicate that individual growers who used many of the practices in one of the categories also tended to use many of the practices in the other categories of the cluster, and vice versa, those who used few in one category also used few in another category. Furthermore, we can see that the Environmental Stewards were strongly associated with the biologically integrated categories, while the Production Maximizers were most associated with the conventional and chemically oriented categories. The Networking Entrepreneurs were not strongly associated with any of the categories nor with either of the other two groups of farmers. On the horizontal scale, which suggests an environmental ranking, they are situated between the two main clusters, but closer to the biologically integrated cluster. Their vertical distance from any cluster may be a reflection of a large within-group variability that prevents the group as a whole from being placed in proximity to any one particular cluster. This variability may stem from the fact that the group was comprised of some farmers who were business-minded like Production Maximizers and others who shared some key characteristics with Environmental Stewards.

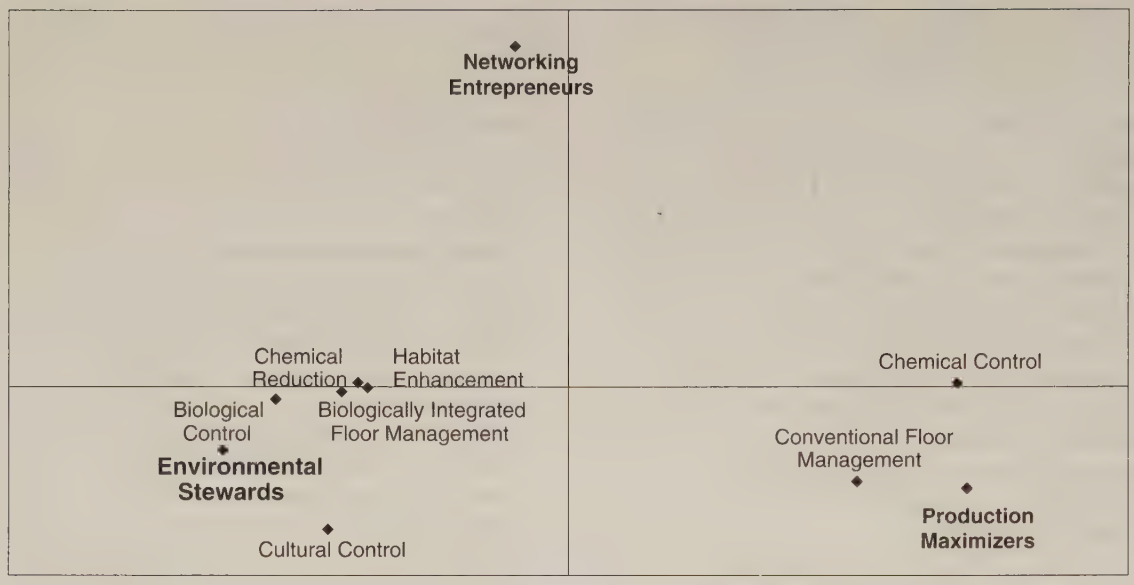

Figure 2. Correspondence analysis of management style groups and adoption of aggregated farming practices in 1998.

These preliminary suggestions of differences between management styles are corroborated by a more comprehensive analysis testing Kendall's tau b value on the aggregated data from both years of the study. The greatest differences between Q-groups were revealed for Cultural Pest Control, Prophylactic and Synthetic Chemicals, Biologically Integrated Floor Management, and Wildlife Habitat Enhancement. In each of these cases, except cultural pest control, the Environmental Stewards differed substantially from the other two groups in using more biologically integrated and environmentally benign practices and fewer synthetic pesticides. We found that the Environmental Stewards distinguished themselves most in their low use of broad-spectrum insecticides, their creation of wildlife habitat and their use of 'softer', less toxic pesticide sprays (tau b > 0.3). Only in the category of Cultural Pest Control did the Production Maximizers exhibit a pattern similar to that of the Environmental Stewards, while the Networking Entrepreneurs stood out most in their low adoption of these practices (Table 3).

Certain members of the Entrepreneurs group also stood out in their low use of some individual practices, including use of less-toxic insecticides (under Reduction of Toxic Chemicals) and chipping and shredding of prunings (under Biologically Integrated Floor Management). These practices, as well as several cultural control practices, could

Table 3. Categories of farming practices showing substantial differences in adoption between management styles.

Pairwise comparisons by category of practices	Tau b[1]
Cultural Pest Control	
Environmental Stewards and Production Maximizers	0.00
Networking Entrepreneurs and Environmental Stewards	0.42
Networking Entrepreneurs and Production Maximizers	0.41
Prophylactic and Synthetic Chemicals	
Environmental Stewards and Production Maximizers	0.45
Environmental Stewards and Networking Entrepreneurs	0.37
Networking Entrepreneurs and Production Maximizers	0.10
Biologically Integrated Floor Management	
Production Maximizers and Environmental Stewards	0.42
Networking Entrepreneurs and Environmental Stewards	0.32
Production Maximizers and Networking Entrepreneurs	0.02
Wildlife Habitat Enhancement	
Production Maximizers and Environmental Stewards	0.54
Networking Entrepreneurs and Environmental Stewards	0.33
Production Maximizers and Networking Entrepreneurs	0.13

[1] Tau b values range from −1 to +1, with values closer to |1| indicating greater differences between groups. Positive values indicate higher use by the second member of the pair, as listed. Conversely, negative values would indicate less use by the second member of the pair.

all impose higher costs in materials, equipment and labor than their counterpart conventional practices. This observation points to an important distinguishing characteristic of Networking Entrepreneurs, their strong off-farm interests and commitments, which may motivate them to use mainly those practices that fit best into their time and management constraints.

Differences between crops. While the two crops were almost equally represented among the Environmental Stewards and Production Maximizers, almond growers comprised almost 75% of the Networking Entrepreneurs, meaning that this group was highly influenced by its almond grower contingency. Examination of the data for individual practices reveals that almond growing Entrepreneurs were particularly unlikely to use softer or less toxic insecticidal sprays and to chip and shred their prunings. Overall, they showed lower adoption of the categories Cultural Pest Control, Reduction of Toxic Chemicals and Biologically Integrated Floor Management, compared to other almond growers (tau b ranging from 0.3 to 0.8).

Winegrape growers in the Entrepreneur group, on the other hand, did not differ as much from winegrape growers in the other two groups (tau b ranging from 0.0 to 0.5). The only noteworthy distinction was the greater tendency of those in the Networking Entrepreneur group to follow strategies to reduce the amounts of toxic pesticides used compared to winegrape growers in the other two groups (tau $b = 0.3$ and 0.5). Almond growing Networking Entrepreneurs, in contrast, were less likely to use such strategies (tau $b = -0.3$ and -0.5).

Certain types of biologically integrated practices appealed more to all winegrape growers as a group, while others appealed more to almond growers as a group, regardless of management style. Winegrape growers were less likely than almond growers to use broad-spectrum and routine pesticide applications, to grow cover crops as habitat for beneficial organisms, or to remove and destroy mummies for sanitation (tau b from 0.27 to 0.46). They were more likely to use the newer forms of less toxic pesticides (tau $b = 0.28$). The role of almond growers in distinguishing the Networking Entrepreneurs also suggests that almond growers in this sample exhibited a greater range of management styles overall than did the winegrape growers.

With the exception of the less toxic but more expensive pesticides, the winegrape growers' adoption pattern suggests an overall strategy of reducing input and labor costs, which is, at least in part, due to the fact that many of the winegrape growers in this study produced high-value varieties for which quality is more important, and often more lucrative, than quantity. Since high quality in winegrapes often occurs inversely to high yield, winegrape growers can afford to be relatively less concerned about many of the most prevalent insect and mite pests, since these pests mostly affect the foliage and overall vine vigor, but do not directly affect the quality of the grapes themselves. In fact, lower vine vigor could even be considered an asset rather than a liability in producing higher-quality, higher-priced grapes. The higher prices, at least at the time of this study, also meant that winegrape producers could afford to try the newer, less toxic but more expensive pesticides, because they still had a higher profit margin within which to operate than did almond growers.

On the other hand, price incentives for quality of almonds are relatively minimal, and those that are offered are based on the level of direct damage to nuts caused by insects and diseases. Since certain insects, in particular, can cause substantial damage, the price bonuses provide added incentives for growers to use routine and broad-spectrum sprays as 'insurance policies'. This pattern leaves only those almond growers most dedicated to an environmental orientation using certain practices generally perceived as more risky, such as using less toxic sprays and only spraying after pest thresholds are observed, rather than routinely. Lower prices also give almond growers an incentive to reduce costly tillage operations and allow resident vegetation on the orchard floor. Moreover, winegrape growers have more appearance concerns, relating to the growing agritourism industry in wine-producing regions, which could be contributing to a higher tendency toward 'clean' vineyard floors compared to almond growers.

Differences by program participation. The results for comparing non-program farmers with BIOS/BIFS participant farmers reveal differences that are much smaller than those between management styles (Table 4). In fact, Biologically Integrated Floor Management was the only category with a somewhat notable tau b value, of 0.36, with program participants using more of these practices than non-participants. This result is not surprising, since cover cropping is one of the practices highly promoted in the BIOS/BIFS programs. Reduction in use of prophylactic and synthetic chemicals, as well as use of biological pest controls, showed a smaller difference, as both of these were also frequently adopted by non-participants. The distribution of participants among the management style groups tells a similar story. While the Environmental Stewards group did have a larger proportion of BIOS/BIFS participants

Table 4. Differences in adoption of farming practices between BIOS/BIFS non-participants and participants.

Categories of practices	Kendall's tau b value comparing BIOS/BIFS non-participants and participants
Biological Pest Control	0.20
Cultural Pest Control	0.05
Prophylactic and Synthetic Chemicals	−0.17
Reduce Toxic Chemicals	0.24
Biologically Integrated Floor Management	0.36
Conventional Floor Management	0.09
Wildlife Habitat Enhancement	0.17

(76% of the group) than the Production Maximizers group (29%, tau b = 0.45), our sample included four non-participants who were Environmental Stewards and four participants who were Production Maximizers. These results show that the BIOS and BIFS programs are appealing sources of information to a wide range of farmers in terms of management styles, whether or not they can immediately adopt all the recommended practices. In addition, those not officially enrolled in the programs may also be accessing the information, either directly or indirectly through other farmers, or they may be making changes in their farm operations due to broader-based environmental and regulatory influences that affect everyone.

Moreover, the lack of substantial differences between BIOS/BIFS growers and non-BIOS/BIFS growers was limited to basic *adoption* of practices, i.e., whether they had been implemented on any part of a grower's acreage. Villarejo and Moore[19] have shown that program growers do differ substantially from non-participants in the *intensity* of use of particular practices, measured in pounds of pesticides applied per acre and in percentage of acres treated.

Crop performance and its relation to farming practices

To assess whether management styles influence crop performance, we examined crop performance data from participating farmers. The mean almond nut reject level was 1.5% [standard deviation (SD) 1.4%, range 0.2–4.6%] for 15 growers from whom data could be collected in 1999. Performance did not differ significantly either between management style groups ($P = 0.28$) or between participants and non-participants of BIOS/BIFS ($P = 0.81$). Seven of the 15 growers had levels under 1%, which frequently brings a price bonus, while one grower, with organic acreage, had a reject level over 4%, which often incurs a price penalty. Leaf nutrient data revealed neither deficient nor toxic levels of any major macro- and micronutrients for the 20 growers whose orchards were tested. These results are comparable to those obtained in a 3-year comparison study of seven conventional and seven BIOS almond orchards, in which overall insect infestation rates were low and not significantly different in sprayed and unsprayed orchards[20].

The mean vine balance ratio in 2000 was 7.9 for the 12 (out of 19) winegrape growers from whom measurements could be obtained (SD 2.8, range 2.8–11.7). As mentioned previously, a ratio between 4 and 8 is an indicator of a healthy balance between vegetative growth and fruit production. Significant differences were found between the management style ($P < 0.001$) and between BIFS participant and non-participant groups ($P < 0.001$). The Production Maximizers had a much higher mean ratio (10.5) than the Environmental Stewards (7.7) and Networking Entrepreneurs (6.6), in keeping with the Production Maximizers' goals of attaining high yields.

The non-BIFS winegrape growers had a much higher mean vine balance ratio (9.8) than did the BIFS participants (6.9). While this sample is not necessarily representative of all growers, these results do point to some crucial differences among winegrape growers in this region. Growers can choose between two different production and marketing strategies—either to grow premium varieties that are used for varietal wines and command high prices, or to grow blending varieties that are marketed as commodities. Since flavor components are improved when vines are not overly vigorous and yields are smaller, wineries pay significantly more (from \$US650 to \$US800 ton^{-1} at the time of the study) for varietal grapes grown under low-input conditions. Prices for blending varieties are typically much lower (from \$US250 to \$US450 ton^{-1} at the time of the study). Growers of these blending varieties therefore tend to manage their vines to emphasize yield, reflected in higher vine balance ratios. As a general marketing strategy, the LWWC, which includes all the BIFS participants in this study and about three-quarters of the winegrape Environmental Stewards, has emphasized higher-quality varieties that can be identified with this region. The other growers, in the same county with the same growing conditions but just outside of the Lodi-Woodbridge jurisdiction, tend to grow lower-value blending varieties, which explains their higher vine balance ratios.

The distinction between winegrape varieties also made a difference in choice of pest management practices used. Growers of high-value varieties were more likely to monitor beneficial mites, to treat 'hot spots' in their fields with miticides, and to use leaf pulling to control insects and disease (tau b = 0.32, 0.40 and 0.42, respectively). These practices are management and labor intensive. High-value producers were also more likely to apply materials such as miticides at below the recommended label rates (tau b = 0.29), because they could afford to be more vigilant in monitoring and spraying hot spots when necessary.

Use of information sources

Data for frequency of information use from 12 sources was aggregated for the 1998 and 1999 growing seasons. For the sample overall, the pattern of contact frequencies suggests that pest control advisers (PCAs) tended to be the first sources to which growers turned, with almost three-quarters of growers reporting high use of input-supplier PCAs, and almost one-third reporting high use of independent PCAs. University-based information sources, including Cooperative Extension farm advisors and their newsletters, were also accessed at relatively high rates, although not as often as PCAs. In addition, 85% of the sample growers reported attending meetings and field days held by farm advisors and others, from once a year to once a month. Other growers and family members were also frequently consulted, while Internet sources were seldom consulted.

The results indicate few differences in information use between farm management styles. Almost three-quarters

Table 5. Selected information sources[1] with differences in frequency of use between management styles.

Pairwise comparisons by information source	Tau b
Independent PCA	
Production Maximizers and Environmental Stewards	0.41
Networking Entrepreneurs and Environmental Stewards	0.42
Networking Entrepreneurs and Production Maximizers	0.10
Input-supplier PCA	
Environmental Stewards and Production Maximizers	0.31
Environmental Stewards and Networking Entrepreneurs	0.43
Production Maximizers and Networking Entrepreneurs	0.26
Other growers/friends/family	
Production Maximizers and Environmental Stewards	0.32
Networking Entrepreneurs and Environmental Stewards	0.07
Production Maximizers and Networking Entrepreneurs	0.23

[1] Information sources with tau b values $> |0.3|$.

of all growers consulted BIOS and LWWC program publications relatively frequently (most between once a month and once a year). These results suggest that most growers are interested in alternative information and that print publications may constitute a relatively easy and inexpensive source of this information.

The largest difference between management styles was in the use of the various classes of PCAs, with Environmental Stewards making the most use of independent PCAs and the least use of input-supplier PCAs (Table 5). Production Maximizers used social sources, especially other growers/friends/family, less frequently than the other two groups, which is consistent with their lower preference for social interaction. Overall, however, differences in use of information sources between management styles were not as distinct as differences in use of practices. This observation supports our hypothesis that adoption of particular practices results from a complex host of farmer attitudes and goals comprising management style.

Among personal contacts, growers with all three styles, including Environmental Stewards, the highest users of independent PCAs, chose input-supplier PCAs as their most important information source. This result is consistent with complaints frequently heard in the field about a shortage of qualified independent PCAs. Farm advisors figure prominently as second and third choices. These results correspond closely to those found in two other recent studies[7,21]. It appears that PCAs tend to serve as the first line of inquiry for day-to-day concerns, while farm advisors serve as the second tier of assistance in unusual incidents and emergencies.

Notably, other growers and family members were not important sources of information for the business-minded Production Maximizers, in contrast to their second-choice standing for approximately half the growers in each of the other two groups. Consistent with the social networking emphasis in their Q-sorting results, 38% of Networking Entrepreneurs picked meetings, seminars and field days as their top choices, while the other two groups preferred print channels. Finally, one-quarter of Environmental Stewards picked BIOS and LWWC publications as their third choice. This source did not figure prominently for the other two groups.

Conclusions

Consistent with Ajzen's theory of planned behavior[11], this study shows that farmers who approach farming with different beliefs, values and goals do indeed differ in the day-to-day farm management decisions they make. The unique combination of social and entrepreneurial characteristics of Networking Entrepreneurs, for example, leads them proactively to seek out and try new and environmentally benign practices, while eschewing those biological and cultural practices that are too time-consuming or expensive. Environmental Stewards give greater priority to a larger set of environmentally benign practices, while Production Maximizers prefer practices that constitute a more traditional path to farm business success.

A relation between farm management style and adoption of practices is also supported by a study on IPM adoption by California pear growers, which observed higher rates of adoption of more complex and pro-active IPM technologies by family farmers than by more business-like, non-resident farm managers[3]. The authors postulated that the family farmers' larger interpersonal communication networks, stronger ties to the land, and more time to spend on more management-intensive technologies all contributed to these differences.

The inability of BIOS or BIFS membership to explain differences in adoption of practices reinforces the notion of looking toward management style for edification. The BIOS and BIFS programs are voluntary programs that focus on sharing and refining information, rather than on requiring the use of certain practices. The lack of distinctions between program participants and non-participants suggests that choosing to enroll in the program is more a sign of how much a grower values learning new information and participating in alternative educational formats, rather than implementing particular practices. On the other

hand, the fact that the management style groups differ more substantially from one another in use of practices demonstrates that a grower's commitment and ability to implement biologically integrated practices is best predicted by a combination of personal goals, beliefs and values, and the manner in which these interface with the underlying structural and marketing context. In other words, *obtaining* new information is a distinct activity from *operationalizing* it. These results imply that merely disseminating general information about new practices is not enough; rather, the information must be presented in varied ways to demonstrate how growers can meet divergent goals by adopting the practices (for discussion of related extension issues, see Brodt et al.[22]).

The variability among the three groups' repertoires of practices suggests that growers are adopting individual practices selectively, as opposed to uniformly adopting bundled sets of practices, as also found in the pear study[3]. Because of the complexities of personal and business factors that impact decision-making, each farmer chooses a slightly different combination of practices. This observation suggests that, while scientists and policymakers might desire everyone to adopt a whole spectrum of practices, a more effective approach might be to work with growers to aggregate practices into groups that correspond with specific management goals.

Another perspective on selective adoption is that, except for two organic growers, almost none of the growers, including several Environmental Stewards, felt that they could ever rely solely on biological and cultural practices to the exclusion of any synthetic materials, because they perceived the risks to crop quality to be too great. In a related vein, we noted that several farmers in the study were *adding* IPM-like techniques, especially monitoring and cultural practices, to their set of conventional chemical practices, rather than using these techniques to *reduce* the number of chemical methods. Even the Production Maximizers distinguish themselves from the others not by their lack of use of biological practices, of which they use a fair number, but by their greater reliance on synthetic materials at the same time. These results point to the need for further research on chemical-free and biologically integrated approaches and better grower education to ensure effective implementation. They also make a case for income guarantee crop insurance programs and federal cost-share programs that could help farmers' transition to lower chemical use.

Finally, we agree with Bentley et al.[20] that it is important to continue to demonstrate the success of new management programs to farmers and pest control advisers, as the evidence from crop performance data suggests that farmers' perceptions of the high risk of biologically integrated methods may not always be justified. Most importantly, we have demonstrated that growers of high-value crops are not adverse to change but, in fact, seek it. The questions then become, what characteristics are they looking for in new farming practices, what information do they need, and which outreach format will enable them to learn the most? Answering these questions will be key to increasing adoption of biologically integrated farming systems.

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Book Review

Raising a Stink: The Struggle over Factory Hog Farms in Nebraska. By C. Johnsen. 2003. University of Nebraska Press, Lincoln NB. xii + 180 p. $21.95, ISBN: 0803276176, paperback.

Carolyn Johnsen has written an important little book about hog production, heartland politics and environmental justice. In the scholarly literature, at least, there is a gap in the factory farming literature where politics and power should fit in, especially in the Midwestern context. While environmental, social and economic impacts of factory farms have been investigated, this research has largely neglected political dynamics and, additionally, has mostly taken place in Europe. In large part this is because large-scale hog confinements are a relatively recent phenomenon in the Midwest, emerging as an issue in the mid to late 1990s. Johnsen's book, *Raising a Stink: The Struggle over Factory Hog Farms in Nebraska*, is written at a point when the debate over factory farms in this area had matured sufficiently to be interesting from a political perspective, with a vibrant grassroots movement developed to, in some cases, effectively address grievances of those impacted negatively by these operations, and also a robust alliance working to protect and expand large-scale hog production.

The book is also interesting because the outcome of this struggle is still so unsure. The political negotiation that has already occurred and continues to occur around these issues illustrates the novel challenge that these large-scale production facilities pose to local, state and federal governments. Much of Nebraska was unzoned before the specter of factory farming emerged; now 89 of the state's 93 counties are zoned, a result of local efforts to control the future incursion of large-scale hog confinements. There remain court cases determining local and county rights as regards controlling factory farms. In the state legislature, players usually advocating local control and reduction of state intervention find themselves opposing local government.

The story of modern hog production in Nebraska, as related by Johnsen, illustrates elemental conflicts occurring throughout the rural Midwest, as well as in many other rural areas. The physical sites of contention are often in sparsely populated areas, often poor counties with declining populations and employment opportunities. Conflict occurs between new hog-production facilities and neighboring farms, through actual physical contamination of air and/or water, aesthetic differences and ideological disputes. These arguments occur over fences, in town meetings, on the editorial pages of local newspapers, in the state legislature and, more and more, in the courts.

The debate over factory hog production is not a simple matter of progress versus tree huggers, nor of insatiable agribusiness versus bucolic family farms, nor of invading urbanites with unrealistic expectations about country living versus embattled farmers. In fact, though there is indeed conflict along these lines, that conflict is exacerbated by the institutional limits of the various political entities involved (local, state and federal government) and the state of knowledge and art regarding the technologies involved.

The flip side of the textured complexity of Johnsen's account of hog farming in Nebraska is her tendency to lose the central nugget of meaning in the abundance of details presented. A reader unfamiliar with Nebraska's plethora of small towns and byways would do well to have a state gazetteer on hand to keep track of the innumerable sites discussed, as well as an ongoing chart of the various players involved. There are almost 200 individual names listed in the index, and individuals are outnumbered by place references and organizations. Perhaps due to her roots in journalism, Johnsen presents what, from a social science perspective, at times resembles raw data—stories without that distillation necessary for readers unfamiliar with the details of either Nebraskan politics or the factory farming debate to grasp their significance. While no doubt some readers will appreciate the 'just the facts, ma'am' style, which allows them to glean what they will from the stories, others, myself included, would appreciate more analysis. Johnsen is obviously very familiar with her subject, and I think that reading more of her analysis of the various cases presented would have been rewarding.

However, *Raising a Stink* remains a very useful book for a variety of audiences. It would serve well as a source of readings for undergraduate courses in environmental policy, rural development, sustainable agriculture, or science and ethics. Social scientists and humanist researchers will find Johnsen's description of the various engineering and animal science concepts central to the factory farming debate useful and approachable. Likewise, researchers involved in the environmental or nutritional aspects of large-scale hog production will be interested in the political and social dimensions of these issues.

Conflict over factory farming can be seen as a result of three characteristics that make it a fundamental shift in the way meat is produced. First is the sheer scale at which animal production occurs in these facilities. For example, Johnsen discusses operations with capacities of 48,000 animals. When one considers that each day each pig produces

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two and a half times as much waste as a human, the resulting accumulation of urine and feces adds up quickly, in many cases resulting in an amount of waste that dwarfs that produced by small cities. Secondly, in large-scale hog confinement operations, waste is stored as a liquid, in a clay-lined pit for several months at a time, eventually being sprayed on crop fields. Even in the best of manure pits, there is usually some seepage of waste. Depending on the type of soil and climate, eventually that waste reaches ground or surface water, potentially contaminating drinking water supplies and aquatic habitat. The third major issue discussed in the debate over factory farming is concern over animal welfare, usually precipitated by the small amount of space allotted to each animal and the type of surface that the animals are kept on (usually concrete), although there are many other concerns that are expressed as well. Johnsen explicitly avoids discussion of animal welfare, confining herself to discussing results of the size of operations and the effects of the liquid manure.

Factory hog farms stink. Even city folks who haven't had the experience of smelling one for themselves will understand this after reading Johnsen's treatment of the issue. The author begins her first chapter with an anecdote about an elderly rural Nebraskan, under duress from the intolerable odors that accompany the 36,000 hog operation next door. Mabel can no longer count on enjoying her garden, and often the stench is apparent indoors as well as out. However, she gives her neighbor, who she has known since he was a child, the benefit of the doubt, and believes he couldn't have known how bad the smell would be. In the chapter titled 'The smell of money', Johnsen presents smell experts who contend that indeed farmers who are continually around hog feces may well not be aware of the smell—that farmers who tell their visitors 'you won't smell a thing' are indeed not being intentionally misleading, since human scent receptors can become immune to smells from ammonia and sulfur dioxide (the primary smelly components of liquid hog feces).

The state of the art of smell detection—at least in a quantifiable way that makes sense to engineers and legislators—is not as advanced as Mabel and others in her position might reasonably expect. Johnsen interviews one family living downwind from 48,000 hogs in which the woman gets headaches from the persistent smell, and the children get diarrhea on days when the smell is bad—almost every day of the summer. She has called the neighbor, who expressed regret, but nothing has changed. The Nebraska Department of Environmental Quality (DEQ) and the Department of Health have not taken action to reduce the smell or hold hog producers responsible for the offensive wafting of smells that sicken their neighbors. The Nebraska legislature has determined that the issue requires more study, and in the mean time there is no way to protect rural residents from the effects.

This seems to be a central theme to Johnsen's book—the state of hard science surrounding factory hog production and its impacts is inadequate to protect people that these operations are affecting. In her chapter titled 'Building on sand', Johnsen describes the challenges of adapting the technology and industry standards developed in places like North Carolina to the utterly dissimilar geophysiology of Nebraska's sandy soils. Even when manure storage lagoons are lined with the industry-standard one-foot-thick clay liner, Nebraska DEQ experts question whether that is sufficient to protect ground water when any breach of that liner, or natural seepage, will result in liquid manure percolating with relative rapidity through the pure sand surrounding the pit.

As we might expect from an experienced journalist, the real strength in Johnsen's book is her stories. The author shows us, in full color, why various players come down on the side they do—whether in favor of increasing hog production in Nebraska or in favor of limiting what producers can do, and how they can do it. Although it is clear that she shares concerns with the opponents of large-scale hog production, its adherents are presented as fully-fleshed humans, with logical, and not always selfish, reasons for favoring these operations. There are thorny problems to be worked out in a region that is trying to retain farmers, trying to regain a modicum of farming profit, and at the same time compete with other areas, both within the US and abroad, that are engaged in their own debate over factory farms.

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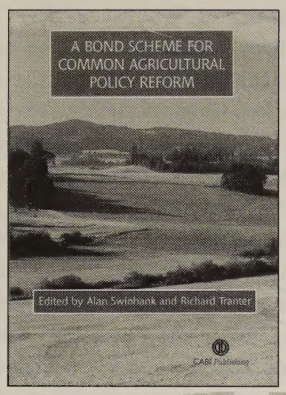

A Bond Scheme for Common Agricultural Policy Reform

Edited by A Swinbank and R Tranter, Centre for Agricultural Strategy, University of Reading, UK

August 2004 208 pages Hardback
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Agricultural economics and policy.

Key Features

- Provides a detailed study of the feasibility and acceptability of deploying a bond scheme to bring about policy change in the EU
- Based upon a substantial survey of farmers' intentions in Germany, Portugal and the UK
- Fills a major gap in existing literature

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The Common Agricultural Policy (CAP) is at an impasse. While it is said that existing policies are not tenable, all recent reform plans have been condemned as unacceptable. However, a "bond scheme", as part of reform that pays more attention to society's aspirations for the environment and rural development, offers a way forward. This book demystifies the bond scheme proposal and explores concerns expressed by farmers and policy makers. Written by economists, a political scientist and a practising politician, it offers rare insights into EU farm policy.

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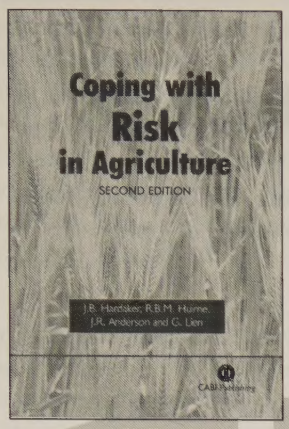

Coping with Risk in Agriculture, 2nd Edition

by J B Hardaker, University of New England, Australia, R B M Huirne, Wageningen University, The Netherlands, J R Anderson, Consultant, Washington DC, USA and G Lien, Norwegian Agricultural Economics Research Institute, Norway

March 2004 352 pages Paperback
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Main Description

The popular first edition of this standard text on risk analysis and management in agriculture has been almost wholly revised. The second edition includes much new material. There is a revised chapter on incorporating decision makers' preferences into the analysis of risky choices that recognizes and gives consideration to some recently published challenges to the legitimacy of the expected utility hypothesis. While it is argued that the theory is still the best way to handle risk aversion, at least in prescriptive analyses, more attention is given to the practical problems of utility function elicitation. It is shown how estimates of (or ranges of) degree of risk aversion might best be obtained and consistently applied.

The new edition has a much more thorough treatment of stochastic simulation, including some novel yet simple methods for dealing to stochastic dependency between uncertain quantities. The treatment of policy aspects of risk in agriculture has been revised and extended to account for such important current issues as new approaches to crop insurance, the management of serious animal and crop diseases and food safety issues. As with the first edition, the book contains a blend of theory with simple illustrative examples to enable readers to see how the principles being discussed can be made operational using modern software.

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